SCIENCE

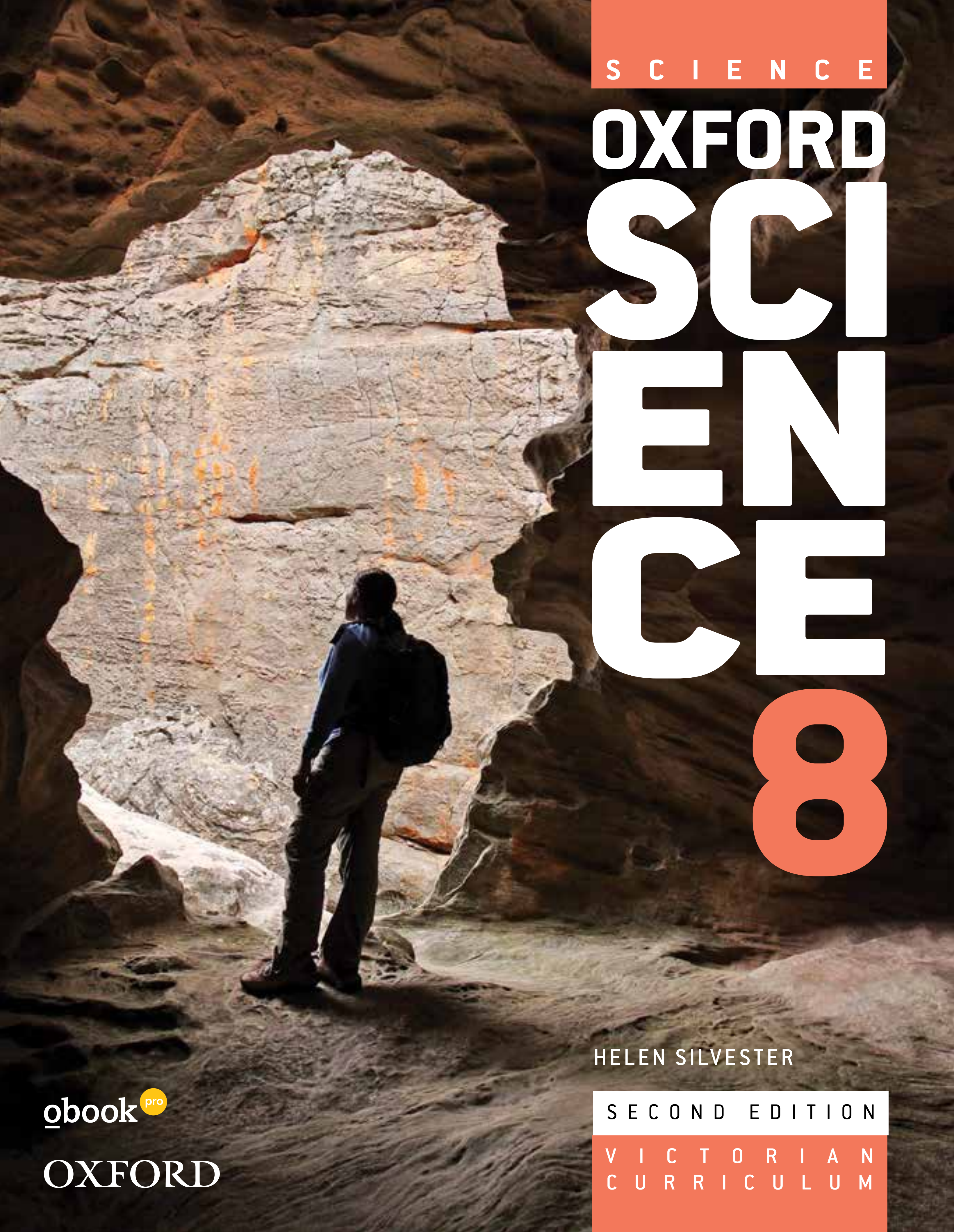
OXFORD SCIENCE 8

HELEN SILVESTER

SECOND EDITION

VICTORIAN CURRICULUM

OXFORD



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obook pro

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Published in Australia by
Oxford University Press
Level 8, 737 Bourke Street, Docklands, Victoria 3008, Australia.

First published 2016
Second edition 2021

NATIONAL
LIBRARY
OF AUSTRALIA

A catalogue record for this
book is available from the
National Library of Australia

ISBN 9780190331887

Edited by Carole Lander
Typeset by Q2A Media Services Pvt. Ltd., Noida, India
Proofread by Kellyanne Martin
Indexed by Max McMaster
Printed in Singapore by Markono Print Media Pte Ltd

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Aboriginal and Torres Strait Islander peoples are advised that this publication may include images or names of people now deceased.

OXFORD SCIENCE 8

1

Science toolkit

Scientists work collaboratively and individually, in the laboratory and in the field, to plan and conduct investigations safely and ethically. Scientists make predictions, control variables and record their results accurately. Scientists communicate their results using scientific language.

2

Rocks and minerals

Rocks have useful properties and can be classified as sedimentary, igneous or metamorphic. Rocks contain minerals and are formed by processes within the Earth over different timescales.

3

Energy

Energy appears in different forms and can be transferred and transformed to cause movement and change.

4

Sound and light

The electromagnetic spectrum is a way of describing all the different forms of light, including the light we see. Sound is caused by the vibration of particles moving in a wavelike motion.

5

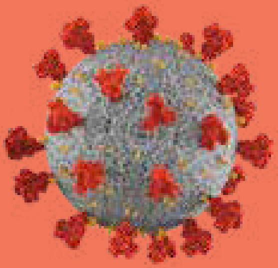
Physical and chemical change

Physical change is a change in the shape or appearance of a substance. Chemical change involves substances reacting to form new substances.

6

Cells

All living things are made of cells. Cells have specialised structures and functions.



7

Surviving

Humans, and other multicellular organisms, survive using systems of organs that carry out specialised functions.

8

Reproducing

Humans, and other multicellular organisms, reproduce sexually or asexually using systems of organs that carry out specialised functions.

9

Experiments

Magnetic fields and movement are used to generate electricity.

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CONTENTS

INTRODUCING *OXFORD SCIENCE 7–10 VICTORIAN CURRICULUM*

Oxford Science Victorian Curriculum has been developed to meet the requirements of the *Victorian Curriculum: Science* across Years 7–10. Taking a concept development approach, each double-page spread of Oxford Science represents **one concept**, **one topic** and **one lesson**. This new edition ensures students build science skills and cross-curriculum capabilities, paving a pathway for science success at VCE.

The series offers a completely integrated suite of print and digital resources to meet your needs, including:

- Student Book
- Student obook pro
- Teacher obook pro.

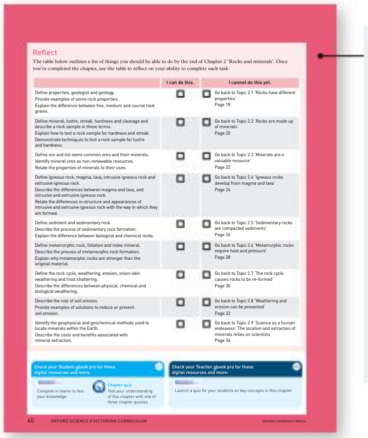
Key features of this Student Book

- This Student Book combines complete curriculum coverage with clear and engaging design.
- Each print Student Book comes with complete access to all the digital resources available on Student obook pro.

Focus on concept development

Chapter openers

- Every chapter begins with a clear learning pathway for students.



Reflect

- Students are encouraged to self-assess their learning against a set of success criteria in the Reflect tables at the end of each chapter. If students do not feel confident about their learning, they are directed back to the relevant topic.

Concept statements

- Every topic begins with a concept statement that summarises the key concept of the topic in one sentence.

Key ideas

- Key ideas are summarised for each topic in succinct dot points.

Integrated links to engaging digital resources

- Where relevant, digital icons flag engaging resources that can be accessed via Student obook pro. These resources are directly integrated with the topic being covered.

Margin glossary terms

- Key terms are bolded in the body in blue text, with a glossary definition provided in the margin.

Check your learning

- Each topic finishes with a set of 'check your learning' questions that are aligned to Bloom's taxonomy. Questions are phrased using bolded task words (also called command verbs), which state what is expected of a student and prepares them for studying VCAA science subjects.

Focus on science inquiry skills and capabilities

Science toolkit

- The Science toolkit is a standalone chapter that explicitly teaches important Science inquiry skills and capabilities.

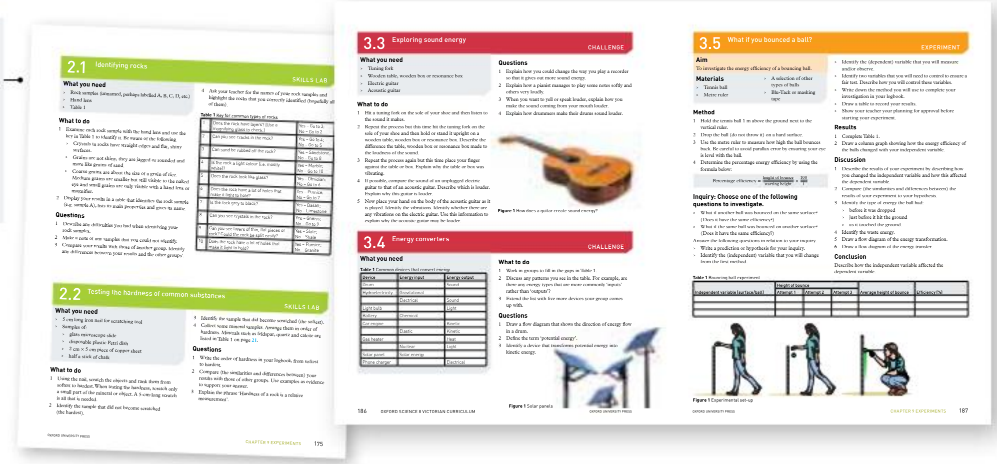
Science as a human endeavour

- 'Science as a human endeavour' topics explore real-world examples and case studies, allowing students to apply science understanding.

Develop your abilities

- 'Develop your abilities' provide scaffolded opportunities for students to apply their science understanding while developing skills and capabilities.

Focus on practical work



Practical work appears at the back of the book

- All practical activities are organised in a chapter at the end of the book and signposted at the point of learning throughout each chapter.

Challenges, Skills labs and Experiments

- These activities provide students with opportunities to use problem-solving and critical thinking, and apply science inquiry skills.

Focus on STEAM

Integrated STEAM projects

- Take the hard work out of cross-curricular learning with engaging STEAM projects. Two fully integrated projects are included at the end of each book in the series, and are scaffolded and mapped to the Science, Maths and Humanities curricula. The same projects also feature in the corresponding Oxford Humanities and Oxford Maths series to assist cross-curricular learning.

Problem solving through design thinking

- Each STEAM project investigates a real-world problem that students are encouraged to problem solve using design thinking.

Full digital support

- Each STEAM project is supported by a wealth of digital resources, including student booklets (to scaffold students through the design-thinking process of each project), videos to support key concepts and skills, and implementation and assessment advice for teachers.

Key features of Student obook pro

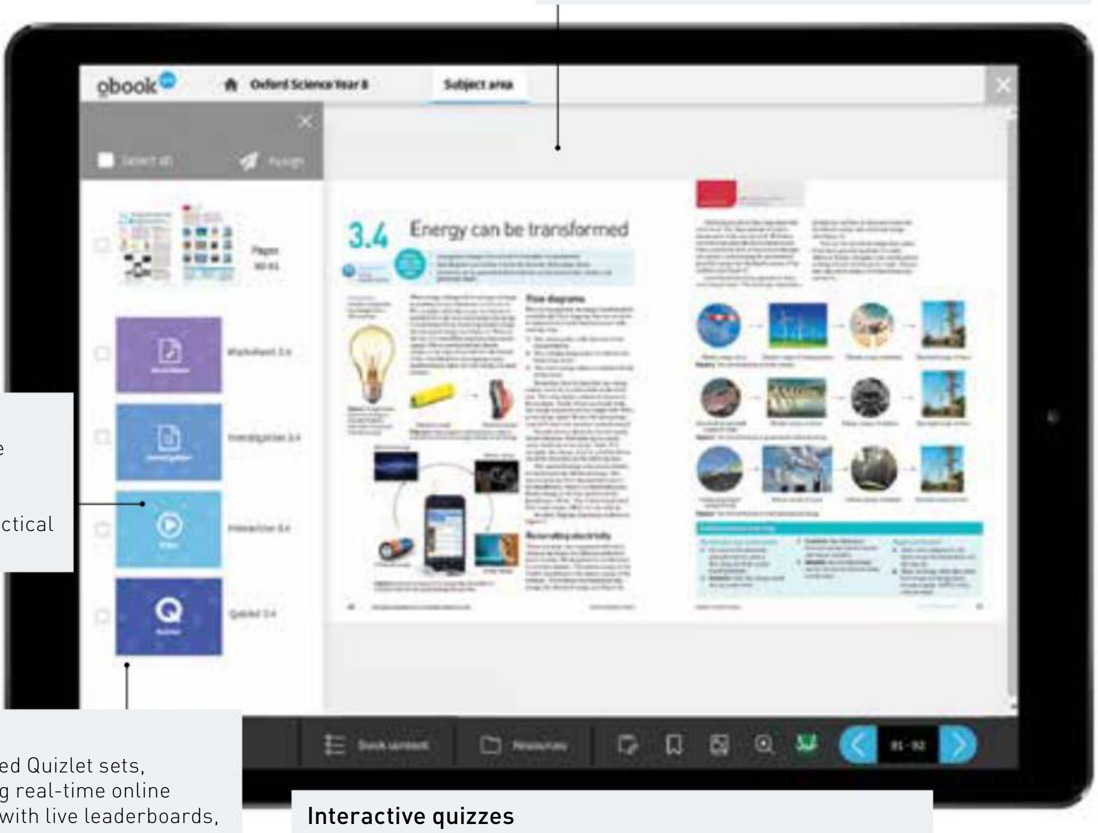
obook pro

- > Student obook pro is a completely digital product delivered via Oxford's online learning platform, **Oxford Digital**.
- > It offers a complete digital version of the Student Book with interactive note-taking, highlighting and bookmarking functionality, allowing students to revisit points of learning.
- > A complete ePDF of the Student Book is also available for download for offline use and read-aloud functionality.

Focus on eLearning

Complete digital version of the Student Book

- This digital version of the Student Book is true to the print version, making it easy to navigate and transition between print and digital.



Videos

- Videos are available online to support understanding of concepts or key practical activities.

Quizlet

- Integrated Quizlet sets, including real-time online quizzes with live leaderboards, motivate students by providing interactive games that can be played solo or as a class. Quizlet can be used for revision or as a topic is introduced to keep students engaged.

Interactive quizzes

- Each topic in the Student Book is accompanied by an interactive assessment that can be used to consolidate concepts and skills.
- These interactive quizzes are autocorrecting, with students receiving instant feedback on achievement and progress. Students can also access all their online assessment results to track their own progress and reflect on their learning.

Benefits for students

- > integrated Australian Concise Oxford Dictionary look up feature
- > targeted instructional videos for key concepts, practicals and worked examples
- > interactive assessments to consolidate understanding
- > integrated Quizlet sets, including real-time online quizzes with live leaderboards
- > access to their online assessment results to track their own progress.

Key features of Teacher obook pro

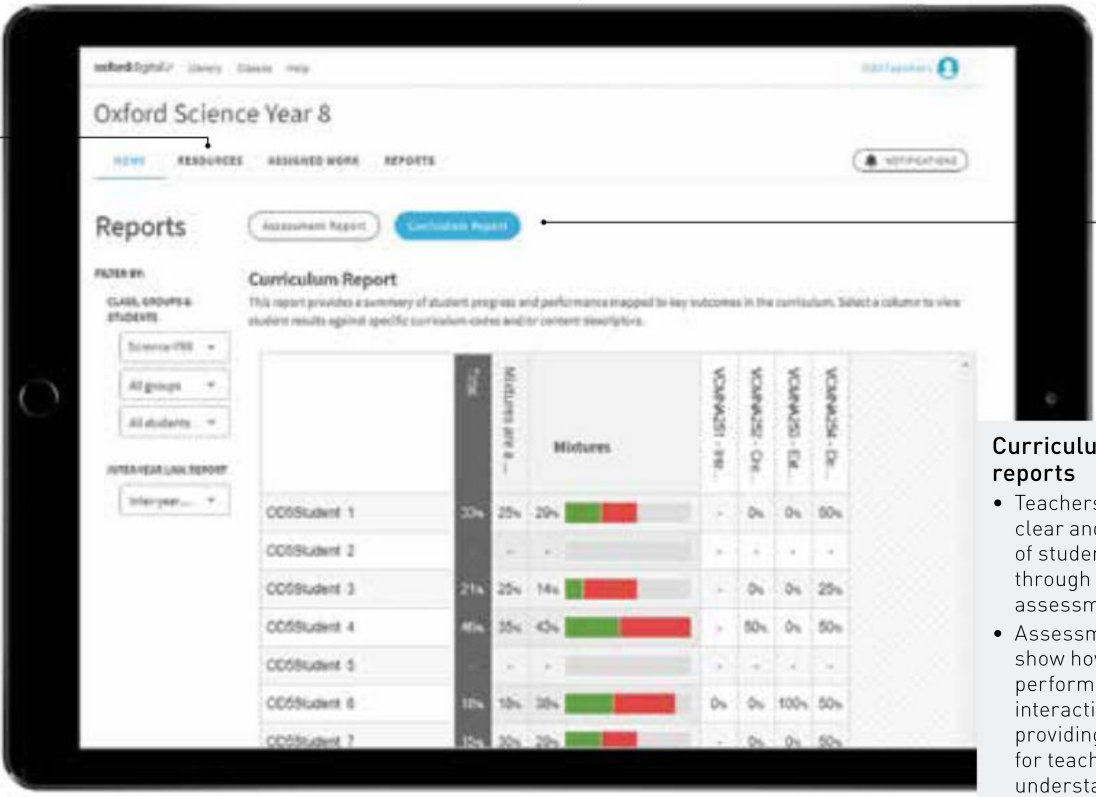
obook pro

- Teacher obook pro is a completely digital product delivered via **Oxford Digital**.
- Each chapter and topic of the Student Book is accompanied by full teaching support. Teaching programs are provided that clearly direct learning pathways throughout each chapter, including ideas for differentiation and practical activities.
- Teachers can use their Teacher obook pro to share notes and easily assign resources or assessments to students, including due dates and email notifications.

Focus on assessment and reporting

Complete teaching support

- Teaching support includes full lesson and assessment planning, ensuring there is more time to focus on students.



Curriculum and assessment reports

- Teachers are provided with clear and tangible evidence of student learning progress through curriculum and assessment reports.
- Assessment reports directly show how students are performing in each online interactive assessment, providing instant feedback for teachers about areas of understanding.
- Curriculum reports summarise student performance against specific curriculum content descriptors and curriculum codes.

Additional resources

- Each chapter of the Student Book is accompanied by additional worksheets and learning resources to help students progress.

Benefits for teachers

- In addition to online assessment, teachers have access to editable class tests that are provided at the conclusion of each chapter. These tests can be used as formative or summative assessment and can be edited to suit the class's learning outcomes.
- Teachers are provided with laboratory support through experiment answer guidance, laboratory technician notes and risk assessments to ensure safe learning experiences.

VICTORIAN CURRICULUM:
SCIENCE 8 SCOPE AND SEQUENCE

LEVELS 7 AND 8 DESCRIPTION

In Levels 7 and 8, the curriculum focus is on explaining phenomena involving science and its applications. Students explain the role of classification in ordering and organising information about living and non-living things. They classify the diversity of life on Earth into major taxonomic groups and consider how the classification of renewable and non-renewable resources depends on the timescale considered. Students classify different forms of energy and describe the role of energy in causing change in systems, including the role of heat and kinetic energy in the rock cycle. They use and develop models including food chains, food webs and the water cycle to represent and analyse the flow of energy and matter through ecosystems and explore the impact of changing components within these systems. Students investigate relationships in the Earth-Sun-Moon system and use models to predict and explain astronomical phenomena. They explain changes in an object's motion by considering the interaction between multiple forces. Students link form and function at a cellular level and explore the organisation and interconnectedness of body systems. Similarly, they explore changes in matter at a particle level, and distinguish between chemical and physical change. Students make accurate measurements and control variables in experiments to analyse relationships between system components and explore and explain these relationships using appropriate representations. They make predictions and propose explanations, drawing on evidence to support their views.

LEVELS 7 AND 8 CONTENT DESCRIPTIONS	
Science as a human endeavour	
Chapter 2, 6, 7 Year 7	Scientific knowledge and understanding of the world changes as new evidence becomes available; science knowledge can develop through collaboration and connecting ideas across the disciplines and practice of science (VCSSU089)
Chapter 3, 5, 7 Year 7	Science and technology contribute to finding solutions to a range of contemporary issues; these solutions may impact on other areas of society and involve ethical considerations (VCSSU090)
Biological sciences	
Year 7	There are differences within and between groups of organisms; classification helps organise this diversity (VCSSU091)
Chapter 6	Cells are the basic units of living things and have specialised structures and functions (VCSSU092)
Year 7	Interactions between organisms can be described in terms of food chains and food webs and can be affected by human activity (VCSSU093)
Chapter 7, 8	Multicellular organisms contain systems of organs that carry out specialised functions that enable them to survive and reproduce (VCSSU094)
Chemical sciences	
Year 7	Mixtures, including solutions, contain a combination of pure substances that can be separated using a range of techniques (VCSSU095)
Year 7	The properties of the different states of matter can be explained in terms of the motion and arrangement of particles (VCSSU096)
Chapter 5	Differences between elements, compounds and mixtures can be described by using a particle model (VCSSU097)
Chapter 5	Chemical change involves substances reacting to form new substances (VCSSU098)
Earth and space sciences	
Year 7	Predictable phenomena on Earth, including seasons and eclipses, are caused by the relative positions of the Sun, Earth and the Moon (VCSSU099)
Year 7	Some of Earth's resources are renewable, but others are non-renewable (VCSSU100)

LEVELS 7 AND 8 CONTENT DESCRIPTIONS	
Year 7	Water is an important resource that cycles through the environment (VCSSU101)
Chapter 2	Sedimentary, igneous and metamorphic rocks contain minerals and are formed by processes that occur within Earth over a variety of timescales (VCSSU102)
Physical sciences	
Year 7	Change to an object's motion is caused by unbalanced forces acting on the object; Earth's gravity pulls objects towards the centre of Earth (VCSSU103)
Chapter 3	Energy appears in different forms including movement (kinetic energy), heat, light, chemical energy and potential energy; devices can change energy from one form to another (VCSSU104)
Chapter 4	Light can form images using the reflective feature of curved mirrors and the refractive feature of lenses, and can disperse to produce a spectrum which is part of a larger spectrum of radiation (VCSSU105)
Chapter 4	The properties of sound can be explained by a wave model (VCSSU106)
SCIENCE INQUIRY SKILLS	
Questioning and predicting	
Chapter 1 Chapter 9 Year 7	Identify questions, problems and claims that can be investigated scientifically and make predictions based on scientific knowledge (VCSIS107)
Planning and conducting	
Chapter 1 Chapter 9 Year 8	Collaboratively and individually plan and conduct a range of investigation types, including fieldwork and experiments, ensuring safety and ehtical guidelines are followed (VCSIS108)
Chapter 1 Chapter 9 Year 8	In fair tests, measure and control variables, and select equipment to collect data with accuracy appropriate to the task (VCSIS109)
Recording and processing	
Chapter 1 Chapter 9 Year 8	Construct and use a range of representations including graphs, keys and models to record and summarise data from student's own investigations and secondary sources, and to represent and analyse patterns and relationships (VCSIS110)
Analysing and evaluating	
Chapter 1 Chapter 9 Year 8	Use scientific knowledge and findings from investigations to identify relationships, evaluate claims and draw conclusions (VCSIS111) Reflect on the method used to investigate a question or solve a problem, including evaluating the quality of the data collected, and identify improvements to the methods (VCSIS112)
Communicating	
All chapters	Communicate ideas, findings and solutions to problems including identifying impacts and limitations of conclusions and using appropriate scientific language and representations (VCSIS113)

ACKNOWLEDGEMENTS

The author and the publisher wish to thank the following reviewers: Professor Bradley Moggridge, James Kennedy, Paguiel Meunier and Michelle Moore.

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CHAPTER

1

SCIENCE TOOLKIT

What questions do scientists ask?

1.1 Science laboratories contain hazards

1.2 Dissection is an important scientific skill

1.3 Scientists design their own experiments

1.4 Scientists keep a logbook and write formal reports

1.5 Tables and graphs are used to present scientific data

What if?

Observations

What you need:

A4 paper, notebook and pen

What to do:

1. Look at one of the pictures on this page for 30 seconds.
2. Cover the picture with the A4 paper.
3. Write down all the things you observed in the picture.
4. Check your answers. How many things did you observe?

What if?

- What if you had more time to observe the picture?
- What if you knew that you had to write an observation list before you viewed the picture?
- What if you repeated the test?

1.1 Science laboratories contain hazards

In this topic, you will learn that:

- science can involve working with hazardous chemicals.
- all hazardous chemicals are identified with warning symbols.
- scientists take safety precautions including wearing lab coats, safety glasses and gloves.
- some chemicals are dangerous for the environment.

hazard
something that has the potential to put a person's health and safety at risk

inhale
breathe in

corrosive
destructive to living tissues such as skin and eyes, or to some types of metals

Figure 1 Lab coats, safety glasses and gloves protect your body and clothing.

Figure 2 Never smell anything in the laboratory unless instructed to. What piece of safety equipment should these students be wearing?

Science is a practical subject that includes hands-on laboratory investigations. You will be using many pieces of equipment, chemicals and other materials that are hazardous. A **hazard** is something that has the potential to put your health and safety at risk.

Chemical safety

A chemical may be listed as hazardous if it is considered dangerous for a person to touch, or **inhale**. Most of the chemicals you will use in your school science laboratory are safe to use provided appropriate precautions are taken. When working with chemicals, you should always wear a buttoned-up lab coat to protect your skin and clothes. Safety glasses should cover your eyes, long hair should be tied back and closed-toe shoes should always be worn. Occasionally you will need to wear gloves. Never taste, smell or mix chemicals unless specifically directed by your teacher, as this may cause a harmful reaction.

When observing chemical reactions ensure that you do not lean over any open containers and never breathe in any gases that may be produced. If your teacher instructs you to smell anything in the laboratory, use your hand to gently waft the gas towards your nose. If you have any concerns tell your teacher immediately.

Hazard symbols

In Australia, and many other countries, hazard symbols (see Figures 3 to 11) are used to indicate the level of risk or danger of a substance. Hazard symbols are required by law in many situations and you may see some in your science laboratory.

Safe disposal of chemicals and other materials

Safely disposing of chemicals is just as important as safely using them. Not everything can be poured down the sink. Some schools have acid neutralising traps in the drains that allow diluted acids to be disposed of in this way. Other chemicals can react with the acid traps or can be toxic for the environment. As a result, these chemicals must be collected at the end of the class and disposed of appropriately by your teacher. These chemicals include **corrosive** liquids, grease and oils, biohazardous wastes and toxic solids. Table 1 lists the safe disposal techniques for various materials.

Table 1 Safe disposal of materials

Material	Examples	What to do with it
Biohazardous waste	Animal cells and tissue	Solids should be collected by your teacher. Deactivate liquid with bleach (1 part bleach to 9 parts water) for 30 minutes before pouring down the drain.
Grease and oils	Vegetable oils Machinery oil	Collect in a bottle and place in regular rubbish. Dispose of as hazardous chemical waste.
Corrosive liquids	Weak acids Strong acids or alkalis	Pour down the drain. Neutralise the acid or alkali and pour down the drain.
Solids	Play dough	Place in regular rubbish.
Hydrogen peroxide	> 8%	Dilute before pouring down the drain.

Figure 3
Health hazard – Substance can cause serious health effects if touched, inhaled or swallowed.

Figure 4
Flammable – Substance can catch fire easily.

Figure 5
Exclamation mark – Substance can cause irritation (redness or rash).

Figure 6
Gas cylinder – Contains gas under pressure. Released gas may be very cold. Gas container may explode if heated.

Figure 7
Corrosive – Substance is corrosive (destructive) to living tissues, such as skin and eyes. (Also used for substances that are corrosive to metals.)

Figure 8
Exploding bomb – Substance may explode if exposed to fire, heat, movement or friction.

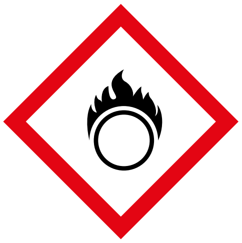

Figure 9
Flame over circle – oxidising – Provides oxygen to make other substances burn more fiercely.

Figure 10
Environmental hazard – Substance is toxic to marine organisms and may cause long-lasting effects on the environment.

Figure 11
Skull and cross bones – toxic – Can cause death if touched, inhaled or swallowed.

Figure 12 Pouring substances down the drain can be a hazard.

1.1 Check your learning

Remember and understand

1 **Describe** the purpose of:
  - a a lab coat
  - b safety glasses
  - c gloves
  - d closed-toe shoes.

2 **Explain** why you would be unlikely to find a substance with the skull and crossbones hazard symbol in a school science laboratory.

3 **Describe** the precautions you might take when using a substance labelled with the exclamation mark hazard symbol.

4 **Describe** why an acid neutralising trap might be used in a laboratory.

Apply and analyse

5 Some acids are considered corrosive. Research the word 'corrosive' and write its definition. **Describe** the precautions you should take when handling acids.

6 **Explain** why you should never randomly mix chemicals together in a science laboratory.

7 Some people are allergic to the latex found in gloves. **Explain** how you could tell if someone is allergic to a substance. **Describe** the alternative safety precautions that might be taken.

1.2 Dissection is an important scientific skill

In this topic, you will learn that:

- scientists use dissection to learn about living organisms.
- dissection requires the use of specialised equipment and techniques.

dissection
the process of disassembling and studying the internal structures of plants, animals and humans

anatomy
the structure of an organism and its component parts; usually refers to human anatomy

Dissections

Dissection (*Latin: to cut to pieces*) is the process of cutting apart and observing something to study it. Although it sounds gory, dissection is an essential learning tool for scientists. Dissecting organs and organisms does not just mean 'chopping them up'. It requires careful techniques to make sure that the tissues are not destroyed so that their structures (**anatomy**) can be examined accurately. Dissection also relies on care being taken with very sharp instruments, such as scalpels.

Surgical instruments of the past

Early anatomists (scientists who did dissections) did not always have access to sterile (clean) and sharp cutting instruments, such as scalpels and precision saws for dissections. Dissections were performed with the same tools that surgeons used in early operations.

Hands-on dissection

Some science skills are best learnt by doing! Follow the steps in Skills Lab 1.2 (on page 6) to learn how to dissect a chicken wing.

Safety first

Dissection instruments and workspaces should be cleaned while you are still wearing your safety gear. Your lab coat and gloves should be on before you start your dissection, and they should not come off until the dissection is completely finished – this includes disposal and cleaning! The last things you should do are: remove your gloves and throw them in the bin; wash your hands thoroughly; take off your lab coat and hang it up.

Figure 1 Early surgical equipment

Figure 2 Forceps are used in surgery to control bleeding.

Figure 3 Scissors – used for cutting skin and other tissue. Dissection scissors often have rounded tips, which are less destructive to the tissue being cut.

Figure 4 Probe – used to look at and explore a specimen, and to probe openings.

Figure 5 Scalpel – small and extremely sharp steel blade used for precision cutting.

Figure 6 Forceps or tweezers – hinged instrument used for grasping and holding tissues.

1.2 Check your learning

Remember and understand

1 **Contrast** (describe the differences between) dissection and cutting something up.

2 **Describe** why dissection is a useful tool for scientists.

3 List three important safety rules that you must follow during a dissection.

4 **Name** three tools that are used as part of a dissection. Include a sketch of each tool.

5 **Explain** why lab coats and gloves should be left on until *after* the clean-up.

Apply and analyse

6 **Explain** why our knowledge of human anatomy would be less advanced without dissection.

7 **Explain** why it might be important for a surgeon to be skilled at dissection.

8 Draw your own surgical tool of the past. Write a description of this tool and give it a name.

1.2 Dissecting a chicken wing

SKILLS LAB

Materials

- Chicken wing
- Newspaper
- Dissection board
- Forceps
- Probe
- Scalpel
- Dissection scissors
- Plastic bag for disposal

Here you will dissect a chicken wing, and step by step, you will practise the correct skills and techniques of dissection to ensure you stay safe and sterile.

After dissecting your specimen, draw a labelled diagram.

Step 1 Make sure you are wearing appropriate safety gear: gloves, lab coat and safety glasses.

Step 2 Set up your workspace, covering surfaces with newspaper that can be disposed of easily and collecting any dissection tools you may need.

Step 3 Collect your specimen for dissection. Identify all external structures.

Step 4 You may want to pin the specimen to the dissection board to keep it from moving.

Step 5 Use probes to look inside any folds.

Step 6 Use forceps to hold and pull tissue.

Step 7 Use scalpels to cut carefully away from your hands. Run the scalpel gently over the tissue several times to cut through. Do not dig the scalpel into the specimen or expect to cut through it in one movement.

Step 8 Use scissors to cut when you can see what's under the structure you're cutting. Scissors with rounded ends are less likely to cause unnecessary damage than those with pointed ends.

Step 9 Fingers are always the least damaging way to 'look around' your specimen.

Step 10 When finished, your specimen should be wrapped in newspaper for disposal. Your instruments should be rinsed, cleaned and disinfected, and your hands should be washed thoroughly.

1

2

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Figure 7 A scalpel

1.3 Scientists design their own experiments

In this topic, you will learn that:

- fair testing occurs when experiments are carefully controlled.
- a variable is something that can affect the outcome of an experiment.
- an independent variable is the variable that the experimenter changes.
- the dependent variable may change as a result of the experiment.

As a scientist you will need to design your own experiments that can be repeated by other scientists. This requires you to control all the variables in the experiment. This is called **fair testing**.

Balloon rockets

Before continuing, complete Experiment 1.3A.

Asking 'What if?'

A **variable** is something that can affect the results of an experiment. You can find out how a variable affects the results by asking a 'what if' question.

> What if the balloon was blown up more?
> What if the string had less friction?
> What if the string had more friction?
> What if the straw was shorter?

Each of these questions asked what would happen if the **independent variable** was increased or decreased. In a fair test, only one variable should be changed at one time.

The impact of this change is measured at the end of the experiment. This is called the **dependent variable**. In this experiment, the dependent variable is the distance the balloon rocket travels. All the other variables must be kept the same. They are called **controlled variables**.

Each experiment should be repeated at least three times. If an experiment is only completed once, a random error could cause a random result. If an experiment is repeated, obtaining the same result twice may be a coincidence. If an experiment is repeated three times and the same result is obtained, then the results can be trusted.

Now try changing the independent variable in Experiment 1.3B in the Experiments chapter.

fair testing
an experiment where only the independent variable is changed and all other variables are kept constant

variable
something that can affect the outcome or results of an experiment

independent variable
a variable (factor) that is changed in an experiment

dependent variable
a variable in an experiment that may change as a result of changes to the independent variable

controlled variables
variables that remain unchanged during an experiment

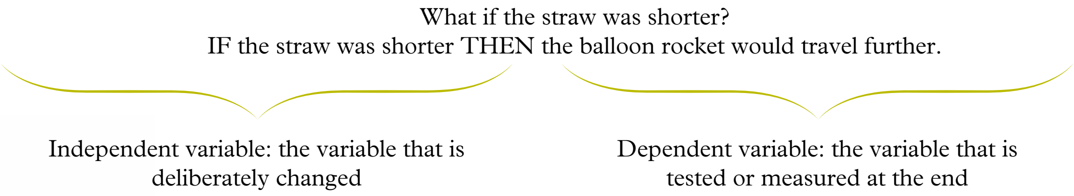


Figure 1 A prediction (or hypothesis) describes the expected relationship between the independent variable and the dependent variable. A 'what if' question can be changed into a prediction by removing the 'what' at the start, and adding a 'then' at the end of the question.

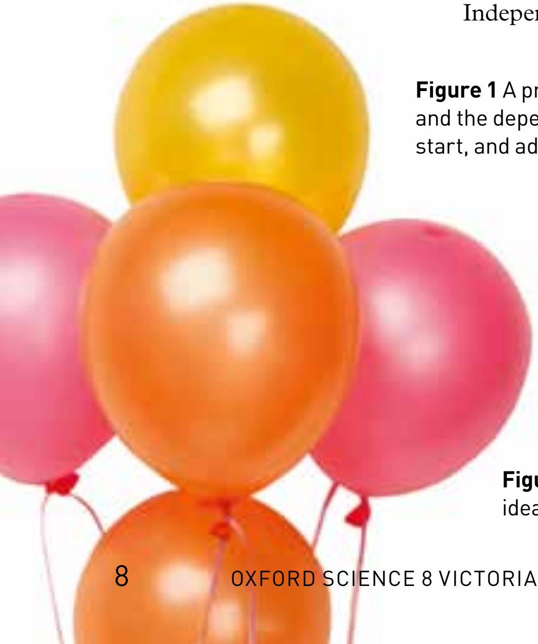


Figure 2 Asking 'what if' about an idea can help make a prediction.

EXPERIMENT

1.3B: Changing the independent variable
Go to page **173**.

1.3A Making a balloon rocket

EXPERIMENT

Materials

- 1 balloon
- 1 long piece of string
- Sticky tape
- 1 plastic straw
- Measuring tape

Method

1 Tie one end of the string to a chair.

2 Place the other end of the string through the straw.

3 Tie the loose end of the string to a second support (another chair) so that the string is pulled tight.

4 Blow the balloon up and stick it to the straw. (Do not tie the end of the balloon.)

5 Measure the circumference of the balloon with the measuring tape.

6 Release the end of the balloon so that the straw slides along the string.

7 Measure how far the balloon rocket moved along the string.

8 Repeat this experiment twice more with the same balloon blown up the same amount. You now have a reproducible test for your balloon rocket.

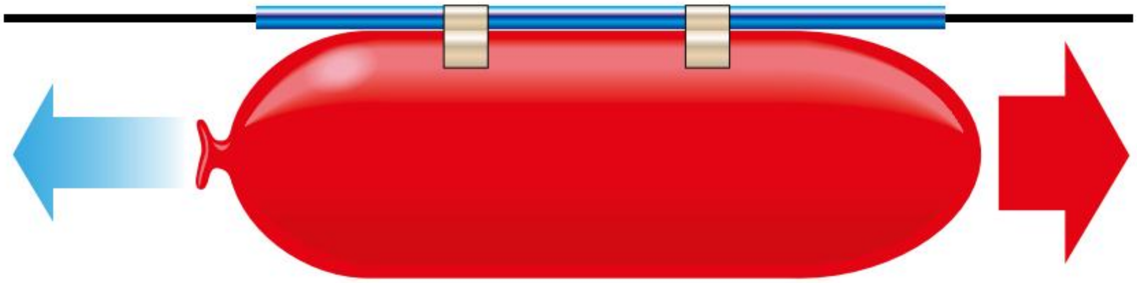


Figure 3 When the balloon rocket is released, the straw will slide along the string.

1.3 Check your learning

Remember and understand

1 **Identify** the three types of variables in an experiment.

2 **Explain** why it is important for an experiment to be reproducible.

3 **Describe** how to change a 'what if' question into a prediction. Use one of the 'what if' questions above that you did not test as an example.

4 **Identify** one variable that you could not control in your balloon rocket experiment.

Apply and analyse

5 Most experimental methods are checked by other scientists. **Explain** why this is important for the results of an experiment to be trusted.

Evaluate and create

6 Many experimental reports written by scientists are peer-reviewed. Research what is meant by the term 'peer-reviewed' and write a definition in your own words.

7 A student wanted to convert their science question into a hypothesis (a possible explanation that can be tested in a fair test). Complete the steps below to help the student.

- Science question: What if smooth fishing line was used for a balloon rocket?
- Science prediction: If smooth fishing line was used for a balloon rocket then …
- Science hypothesis: If smooth fishing line was used for a balloon rocket then … because …

1.4 Scientists keep a logbook and write formal reports

In this topic, you will learn that:

- a science logbook is used to record the details of the work done in a science laboratory.
- a logbook provides evidence of the planning, changes and results of an experiment.

There are many different types of science and even more types of science experiments. Some experiments last a few minutes, while others can last many years. An example of a long experiment is an ecologist recording how the number of dolphins in Port Phillip Bay or the Gippsland Lake changes over a decade (10 years). All experiments rely on the scientists collecting and recording data and observations in an electronic or written logbook. Logbooks contain all of the information that is used to write a formal report (a written report used to communicate the results of an experiment with other scientists).

Creating a logbook

There are some basic rules to creating and using a logbook.

1. Use a bound notebook or an electronic device that is backed up regularly. Loose papers become lost, and electronic devices can fail. Ensure that the style of records you use is reliable.
2. Label your logbook with your name, phone number, email address, school and teacher's name. Logbooks can become lost. Labelling the logbook with your contact details (and those of your school and teacher) ensures that it will find its way back to you.
3. The second page of the logbook should contain a table of contents. Each page should be numbered to help you find the relevant experiments.

Unit/subject	Experiment title	Page number

4. Always date every entry.
5. Each page should contain the title of the experiment.

Figure 1 Logbooks contain important data and observations from experiments.

Figure 2 A bound notebook is one option that can be used for a logbook.

1.4 Check your learning

Remember and understand

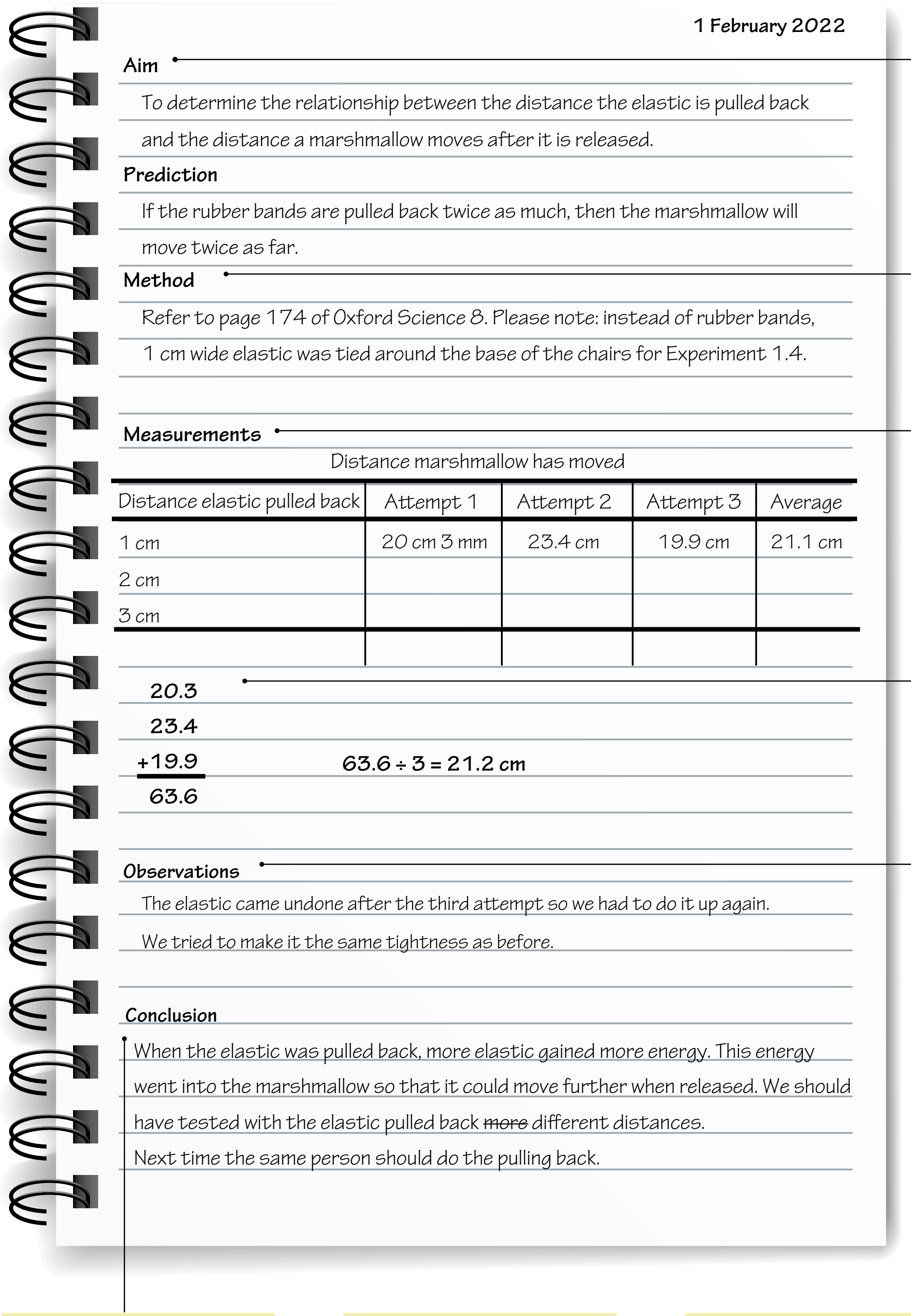
1. **Describe** the purpose of a laboratory logbook.
2. **Explain** why an electronic logbook should be backed up regularly.

Apply and analyse

3. A student made a mistake and ripped the page out of their logbook. **Explain** why this would be the wrong thing to do.
4. **Explain** why it is important to make sure the writing in your logbook is legible (able to be read).
5. **Contrast** (the differences between) a logbook and a formal science report.
6. **Identify** one reason why it is important to include the date of the experiment in the logbook.
7. **Explain** why you should reflect on each experiment before starting the next experiment.

EXPERIMENT

1.4: Marshmallow slingshots
Go to page **174**.



1 February 2022

Aim

To determine the relationship between the distance the elastic is pulled back and the distance a marshmallow moves after it is released.

Prediction

If the rubber bands are pulled back twice as much, then the marshmallow will move twice as far.

Method

Refer to page 174 of Oxford Science 8. Please note: instead of rubber bands, 1 cm wide elastic was tied around the base of the chairs for Experiment 1.4.

Measurements

	Distance marshmallow has moved			
Distance elastic pulled back	Attempt 1	Attempt 2	Attempt 3	Average
1 cm	20 cm 3 mm	23.4 cm	19.9 cm	21.1 cm
2 cm				
3 cm				

20.3
23.4
+19.9
63.6

63.6 ÷ 3 = 21.2 cm

Observations

The elastic came undone after the third attempt so we had to do it up again.
We tried to make it the same tightness as before.

Conclusion

When the elastic was pulled back, more elastic gained more energy. This energy went into the marshmallow so that it could move further when released. We should have tested with the elastic pulled back ~~more~~ different distances.
Next time the same person should do the pulling back.

Aim and prediction for the experiment.

The method used or the page number of the method. Record any changes to the method.

Record any measurements you made to the maximum number of digits provided by the equipment. (You can round them off later. If you don’t record them then you cannot get them back later.)

Show all calculations (even when adding simple numbers).

Include any ideas, explanations, diagrams, graphs, sketches or mistakes that happened. Write everything down even if it seems unimportant. You may not remember it weeks or even months later.

Do not rewrite any entries. Try to keep it as neat as you can but it is not a formal report. It is more important that you record your data and observations. If you make a mistake, put a single line through it. Do not white it out, as it may be useful again later.

Include a conclusion or reflection for each experiment to make sure you understood what happened and why.

You may need to write up a formal report for your experiment. If you have completed your logbook well, you will find all the details of the report easily available.

Glue or staple in any photocopies to prevent them falling out.

Figure 3 A sample logbook entry

1.5 Tables and graphs are used to present scientific data

In this topic, you will learn that:

- graphs are a way to display the information (data) gathered in an experiment.
- graphs can be used to identify patterns in the data.
- extrapolation of graphs allows you to predict what might happen if the experiment was continued.

directly proportional relationship
a relationship between two variables in which the dependent variable increases as the independent variable increases

inversely proportional relationship
a relationship between two variables in which the dependent variable decreases as the independent variable increases

Common features in graphs

There are four features all graphs have in common.

1. A descriptive title of what the graph shows.
2. A grid that is used to plot the points or data.
3. The independent variable on the horizontal axis.
4. The dependent variable on the vertical axis.

Interpreting graphs

Line graphs are the most common graphs that are drawn in scientific reports. These graphs are used to show the relationship between the independent variable and the dependent variable. The shape of the graph gives a hint of how the two variables are related.

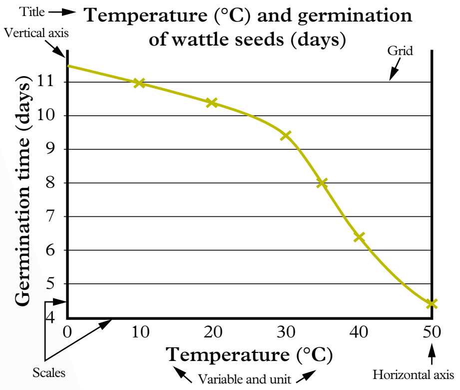


Figure 1 The independent variable (temperature) should be on the horizontal axis and the dependent variable (germination time) should be on the vertical axis.

When the line slopes upwards, this means the dependent variable increases as the independent variable increases. This is called a **directly proportional relationship**.

When the line is horizontal or flat, it means the dependent variable is not affected by the independent variable.

If the line slopes downwards, then the dependent variable decreases as the independent variable increases. This is called an **inversely proportional relationship**.

Occasionally a graph is curved (as shown in Figure 5). These graphs can be considered in sections. In section A (between 1 and 4), the dependent variable increases as the independent variable increases. In section B (between 4 and 7) the dependent variable decreases as the independent variable increases.

Sometimes you may have recorded the results for a set of whole numbers. An example of this is when you pulled back the elastic and marshmallow in the the experiment on page 174 by 1 cm, 2 cm, 3 cm and 4 cm. If you draw an accurate line graph of your data, then you may be able to use the graph to see what would happen if you pulled back the marshmallow by 2.5 cm.

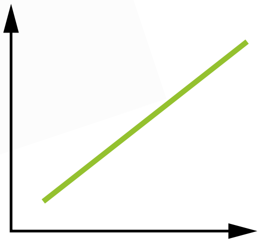


Figure 2 A directly proportional relationship

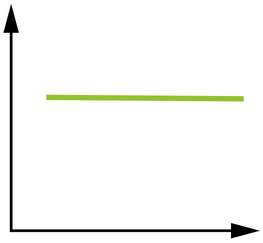


Figure 3 The dependent variable is not affected by the independent variable.

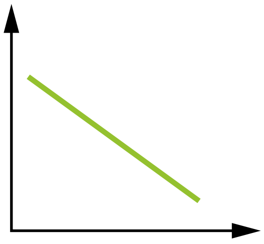


Figure 4 An inversely proportional relationship

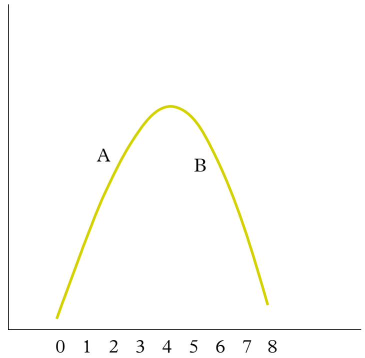


Figure 5 A curved graph is divided into sections.

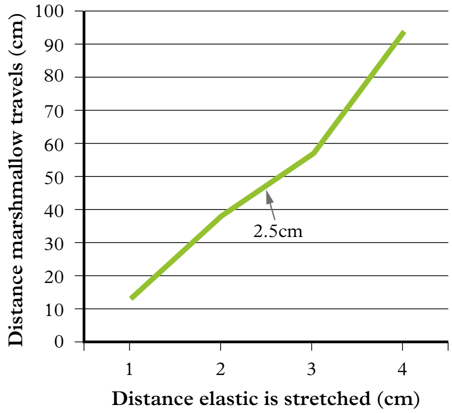


Figure 6 Change in distance travelled by a marshmallow from an elastic slingshot

A graph can also be used to extrapolate results. This means you can continue the shape of the graph to determine what would happen if you continued the experiment. Extrapolating the line needs to be done carefully as it is only a prediction of what might happen. It is not always accurate.

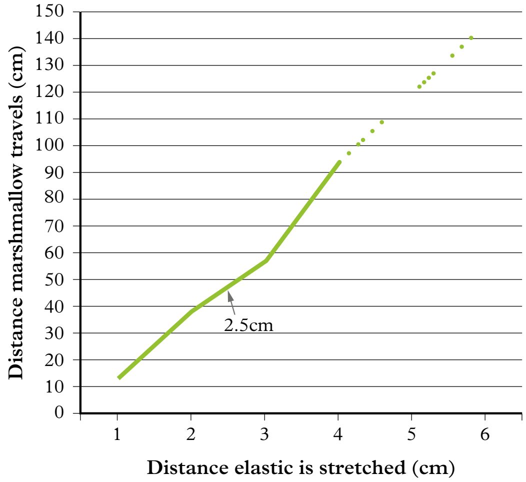


Figure 7 Extrapolating distance travelled by a marshmallow if the elastic was stretched further

1.5 Check your learning

Remember and understand

1 **Identify** the features that all graphs have in common.

2 **Describe** what you are doing when you 'extrapolate the results' of your experiment.

3 **Describe** the relationship between the independent variable and dependent variable in the following graph.

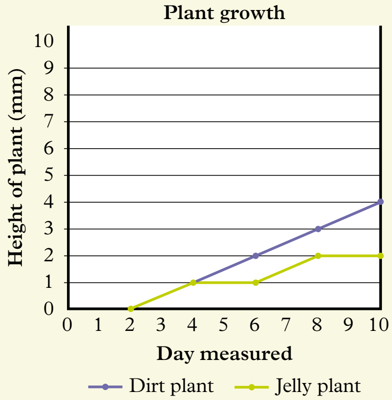


Figure 8 A graph showing plant growth

Apply and analyse

4 Extrapolate the following graph to predict what would happen if the water was heated for 8 minutes.

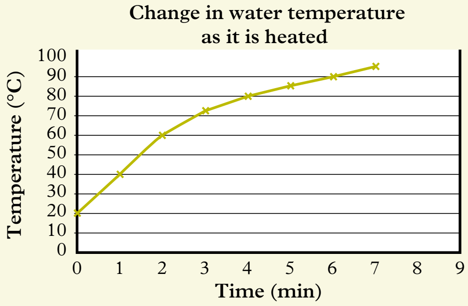


Figure 9 A graph showing the change in water temperature

5 **Explain** why graphs are often used in scientific reports.

6 **Explain** why the extrapolation of a graph (below) showing the life expectancy of a child should not be used to predict the age expectancy of a child born in 2025.

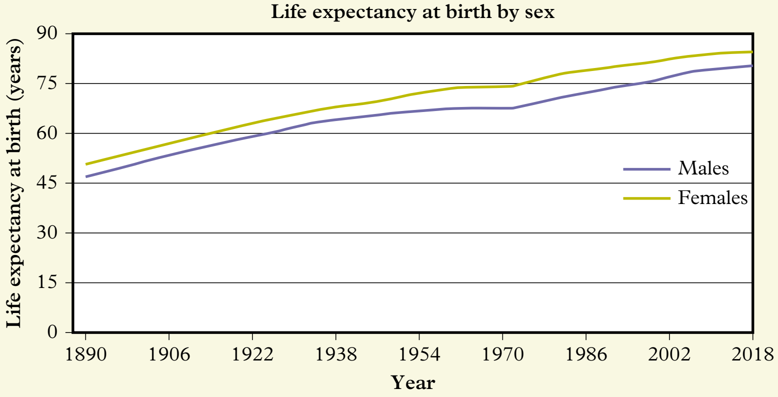


Figure 10 A graph showing life expectancy at birth by sex

REVIEW 1

Multiple choice questions

1 Material that is a health hazard can cause:
- **A** long-lasting effects in the environment
- **B** serious health effects if touched, inhaled or swallowed
- **C** death if touched, inhaled or swallowed
- **D** explosions if exposed to fire, heat, movement or friction.

2 The relationship between the variables shown on the graph in Figure 1 could be described as:
- **A** directly proportional
- **B** inversely proportional
- **C** no direct relationship
- **D** a negative relationship.

3 The variable that is placed on the horizontal axis of a graph is the:
- **A** independent variable
- **B** dependent variable
- **C** controlled variable
- **D** uncontrolled variable.

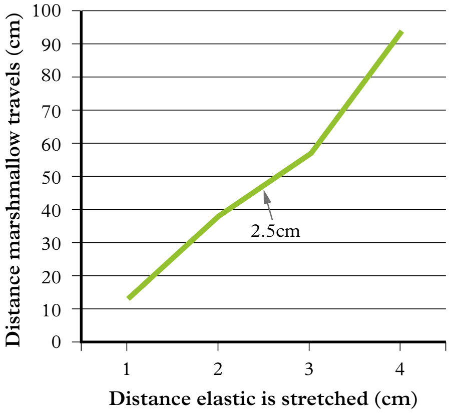


Figure 1 A graph showing distance a marshmallow travels

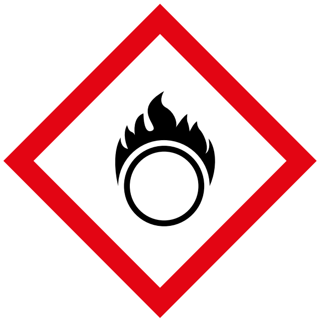
Short answer questions

Remember and understand

4 **Describe** when the following symbols or objects are used.

a

b



c

d

5 **Describe** how you should dispose of hazardous waste from dissections.

6 **Define** the following words:
- **a** dissection
- **b** anatomy
- **c** dependent variable
- **d** prediction.

7 **Describe** the information that should be included in an experimental logbook.

8 **Explain** why it is important to include in your logbook any changes you make to an experimental method.

9 **Identify** the four common features that should be present on all graphs.

10 **Contrast** (the differences between) the independent variable and the dependent variable.

11 **Describe** how you should safely dispose of:
- **a** newspaper used for dissections
- **b** vegetable oil
- **c** weak acid
- **d** strong acid.

12 A scientist observed that as the temperature increased, the flowers on a rose bush started wilting and dropped off the bush. They drew a graph that showed a directly proportional relationship between the temperature and the five flowers on the rose bush. **Explain** why they should not extrapolate the graph beyond the five flowers.

13 **Compare** (the similarities and differences between) the independent variable and the dependent variable.

Apply and analyse

14 **Identify** the dissection tools you have in your science laboratory.

15 **Describe** how you can make sure an experiment is a fair test.

16 **Explain** why you should wash science equipment thoroughly before returning it to the cupboard (by considering what would happen if you did not wash the equipment thoroughly).

17 **Explain** what might happen if you put play dough down the sink.

18 **Explain** when a formal written report should be used.

Evaluate

19 Draw a graph from the data in Table 1 that shows how much Enza has grown in her first 8 years. Extrapolate the results to predict how tall Enza will be when she is 10 years old.

Table 1 Enza's growth over 8 years

Age (years)	Height (cm)
1	75
2	86
3	91
4	99
5	105
6	110
7	117
8	121

20 Answer the following questions about the graph in Figure 2.

- **a** **Identify** the label that should be on the *x*-axis.
- **b** **Identify** the label that should be on the *y*-axis.
- **c** **Identify** which year had the greatest number of road deaths.
- **d** **Identify** the number of road deaths that occurred in 1965.
- **e** **Describe** the trend between:
  - **i** 1945 and 1965
  - **ii** 1975 and 1985
  - **iii** 1990 and 2010.
- **f** **Identify** one factor that could have caused the trend from 1985 to the current day.

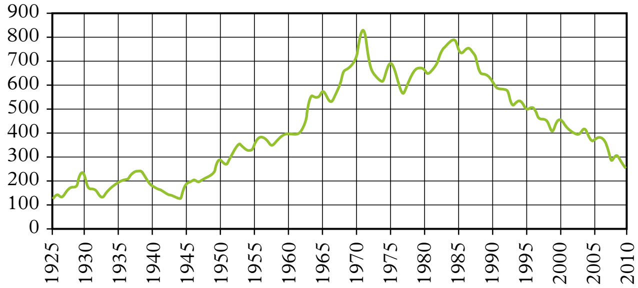


Figure 2 A graph showing the number of road deaths, 1925 to 2010

Social and ethical thinking

21 Dissections and research involving animals have contributed significantly to our understanding of the human body. In fact, it would probably be fair to say that we couldn't have come this far without them. Critically **evaluate** the advantages and disadvantages involved in using animals for medical research purposes. Discuss your points with a partner and share your thoughts with the class.

Figure 3 Should we use animals for medical research purposes?

Critical and creative thinking

22 One of the first scientists to record their dissections was Leonardo da Vinci. Create a picture scrapbook of copies of some of Leonardo da Vinci's best work on the study of the human body.

23 Scientists present formally written reports in scientific journals. Many of these reports must be examined (peer reviewed) by other scientists before they will be accepted for publishing. **Explain** one advantage of the peer review process.

Research

24 Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

» Testing sticky tape

Design an experiment to test the strength of different types of sticky tape. **Identify** your independent variable. Describe how you will measure your dependent variable. List all the variables that could affect the results. Describe how you will control each of these variables. List the materials you will need. Write out a method in a step-by-step manner.

» Early anatomists

Research how early anatomists such as the Egyptians or the Greeks made their discoveries. Describe the relationship between barbers (male hairdressers) and surgeons. Research who they were allowed to dissect legally according to King Henry VIII. Describe how current surgeons learn anatomy.

» Laboratory chemicals

Many chemicals are banned from use in school laboratories. Research one of these chemicals. Identify when it was banned. Explain why it is considered dangerous for use by students. Identify whether it is still used in other workplaces. Describe the precautions that need to be taken by people who work with this chemical.

Reflect

The table below outlines a list of things you should be able to do by the end of Chapter 1 'Science toolkit'. Once you've completed the chapter, use the table to reflect on your ability to complete each task.

	I can do this.	I cannot do this yet.
Describe the purpose of hazard symbols. Provide examples of some potential hazards in a science laboratory. Demonstrate safe behaviour in the laboratory.	☐	☐ Go back to Topic 1.1 'Science laboratories contain hazards' Page 2
Identify the key instruments required for a dissection. Describe the purpose of dissection. Demonstrate safe dissecting skills.	☐	☐ Go back to Topic 1.2 'Dissection is an important scientific skill' Page 4
Describe the key features of a fair test. Provide examples of dependent, independent and controlled variables from scenarios. Explain how to formulate a hypothesis. Demonstrate the ability to follow experimental methods.	☐	☐ Go back to Topic 1.3 'Scientists design their own experiments' Page 8
Describe the information required in each section of an experimental report. Explain the purpose of a logbook.	☐	☐ Go back to Topic 1.4 'Scientists keep a logbook and write formal reports' Page 10
Describe a directly proportional relationship and inversely proportional relationship. Demonstrate the ability to extrapolate data.	☐	☐ Go back to Topic 1.5 'Tables and graphs are used to present scientific data' Page 12

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CHAPTER 2

ROCKS AND MINERALS

Do rocks change?

What if?

Rocks

What you need:

Selection of different rocks for each group

What to do:

1. Divide class into groups of four.
2. Examine each rock carefully. Identify the properties that the rocks have in common and the different features of each rock.
3. Group the rocks according to their similarities. Give each group a name that helps to identify the rocks.
4. Record the names and the properties of the rocks on a piece of paper.

What if?

- » What if another group was given your rocks? Could they use the properties you identified to separate the rocks into the same groups?

2.1 Rocks have different properties

In this topic, you will learn that:

- geologists are scientists who study rocks.
- the characteristics of rock include the colour, presence of layers, hardness, density and crystal size.

properties
in chemistry, the characteristics or things that make a substance unique

geologist
a scientist who studies rocks

Rocks don't all look and feel the same. Each rock has characteristics that give clues to its identity, such as its colour or hardness. These characteristics are referred to as **properties**. By making careful observations of a rock's properties, **geologists** (scientists who study rocks) can tell where a rock came from and what has happened to it.

Identifying and selecting rocks

We select rocks for particular purposes because of their properties. For example, granite is selected for kitchen benchtops because it is the hardest building stone, it is not porous (it does not let liquid through), it is not affected by temperature and it is resistant to damage from chemicals.

You can identify rocks first by how they look. Coal is black or dark brown. Pumice and scoria are covered with holes. Conglomerates are made up of individual stones cemented together. Granite is made up of large crystals of the minerals quartz, mica and feldspar.

Geologists also use a range of other properties to help identify rocks, such as layering, weight and the presence of crystals or grains (see Figures 1 to 5).

Table 1 lists some different types of rocks and how they can be identified.

Table 1 Rock identification

Rock	Grain size	Hardness	Usual colour	Density
Basalt	Fine or mixed	–	Dark	2.8–3
Coal	Fine	Soft	Dark	1.3
Conglomerate	Mixed	Hard or soft	–	–
Gneiss	Coarse	Hard	Alternating light and dark bands	2.3–2.6
Granite	Coarse	Hard	Light	2.6–2.7
Limestone	Fine	Soft	Light	2.3–2.7
Marble	Coarse	Soft	Light	2.4–2.7
Obsidian	Fine	Soft	Dark	2.6
Pumice	Fine	Soft	Light	0.6
Quartzite	Coarse	Hard	Light	2.6–2.8
Rhyolite	Fine	Hard	Light	2.4–2.6
Sandstone	Coarse	Hard	Light	2.2–2.8
Schist	Medium to coarse	Medium	Medium	2.5–2.9
Scoria	Fine	–	Dark	0.9
Shale	Fine	Soft	–	2.4–2.8
Slate	Fine	Soft	Dark	2.7–2.8

Figure 1 Weight and **density** are less if rocks contain large gas holes that were produced when the rock was formed. In pumice, the holes can be the size of a match tip or smaller. In scoria the holes are often the size of a pea.

SKILLS LAB
2.1: Identifying rocks
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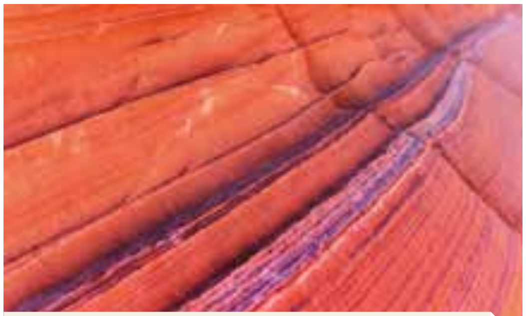

Figure 2 Layers in rocks can look very different. Some rocks have different-coloured layers that line up like ribbons. Gneiss usually has alternating layers of colours, often black and white. Sandstone has layers of different-sized grains of sand. Wind or water distributes the sand so that the rock ends up being different shades of the same colour.

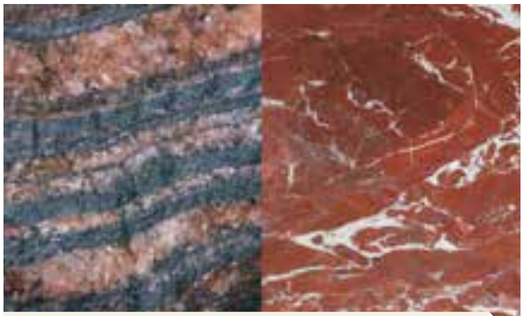

Figure 3 Colour is a property that depends on the chemicals in the rocks. For example, some red rocks contain a lot of iron, which has reacted with oxygen in the air ('rusted') to form red iron oxide. Other red rocks don't contain iron, so a rock cannot be identified solely by its colour.

Figure 4 Crystals are small pieces of organised particles that have smooth sides and sharp edges. They are usually just one colour and often reflect light off their flat surfaces. Crystals in a rock can be different sizes.

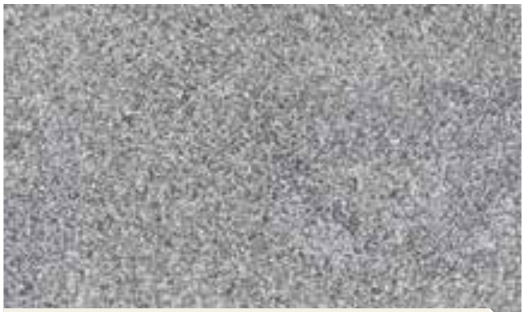

Figure 5 Grains are small pieces of material. The size of the grain can be used to identify the type of rock. Large grains (larger than a grain of rice) are said to be coarse. Smaller grains that can still be seen with the eye are medium grained. Fine grains cannot be seen without a microscope.

Figure 6 Some of the many different types of rocks

2.1 Check your learning

Remember and understand

1 Use Table 1 and Figure 6 to identify these rocks.
  a I am light in colour with a fine grain. I am considered soft.
  b I am light in colour with holes in the surface.
  c I am soft, shiny and dark in colour. I am often used for flooring.
  d I have mixed grains and my colour can vary.

2 **Identify** the properties that are used to identify different types of rocks.

3 **Identify** two different uses for different types of rocks.

4 **Explain** why properties other than colour can be used to identify a rock.

5 **Identify** the branch of science that is the study of rocks.

Apply and analyse

6 Pumice has a density of 0.6. Water has a density of 1. **Predict** if the pumice stone would float or sink. **Justify** your answer (by defining the term 'density', explaining how low-density objects behave in water and comparing this behaviour to pumice in water).

7 **Explain** why pumice would not be an appropriate material for a kitchen bench (by describing the properties needed for a kitchen bench and comparing these properties to the properties of pumice).

2.2 Rocks are made up of minerals

In this topic, you will learn that:

- rocks are made up of one or more minerals.
- a mineral is a naturally occurring solid substance with its own chemical composition, structure and properties.
- there are more than 4000 known minerals.

Interactive 2.2
Classifying rocks

minerals
tiny grains or crystals that are the building blocks of rocks

lustre
the shininess of a mineral

streak
the colour of a powdered or crushed mineral

Properties of minerals

Minerals are organised groups of particles found as crystals (see Figure 1). The structure of a crystal affects the properties of a mineral. For example, diamond and graphite are made up of the same type of particle (atoms) – they are both pure carbon. Graphite (which is the ‘lead’ in a pencil) is very soft, whereas diamond is the hardest of all minerals. This difference arises because the carbon particles in a graphite crystal are arranged into sheets that can slide past each other, whereas the carbon particles in a diamond crystal are interlocked in all directions, preventing them from moving.

Figure 1 The individual mineral crystals of the rock olivine basalt can be seen under a microscope.

Identifying minerals

To identify minerals correctly, geologists carefully examine the properties of rocks.

The colour of a mineral is a guide to identifying it, but it cannot be relied on for correct identification. Colour is not a reliable property because many minerals are impure. For example, pure quartz is colourless, but if it contains impurities it can be many colours, such as purple (amethyst), pink (rose quartz) or yellow (citrine). Even in one sample, the colour may vary.

Lustre is the shininess of the surface of the mineral. Some types of lustre are:

- metallic – looks like a shiny new coin
- brilliant – very shiny, like a mirror
- pearly – a bit shiny, like a pearl or fingernail
- dull – not shiny at all
- earthy – looks like a lump of dirt.

Streak is the colour of the powdered or crushed mineral. This colour can be seen by drawing with the mineral on a footpath. The colour of the line that the mineral leaves behind is its streak. Often the colour of the streak is different from the main colour of the mineral.

Figure 2 a The carbon atoms in the mineral graphite are arranged in sheets. **b** In a diamond, the carbon atoms are interlocked.

SKILLS LAB

2.2: Testing the hardness of common substances
Go to page **175**.

Hardness is how easily a mineral can be scratched. Some minerals are so soft that they can be scratched with a fingernail. Other minerals are so hard that they can scratch glass. A hard mineral can scratch a soft mineral without being damaged itself. Austrian geologist Friedrich Mohs (1773–1839) invented a scale to describe the hardness of a mineral. Mohs gave a hardness number to ten common minerals (see Table 1): the softest mineral, talc, has a hardness of 1; the hardest mineral, diamond, has a hardness of 10. These minerals can be used to find the hardness of any other mineral.

A mineral will scratch another mineral with a lower hardness number but not one with a higher hardness number. So, copper (hardness 3.5) will be scratched by fluorite (hardness 4), but not by calcite (hardness 3). Copper will scratch calcite. Fingernails have a hardness of 2.5; iron nails and glass microscope slides have a hardness of 6.5.

Cleavage is the tendency of a mineral to break into a number of smooth planes. Minerals that demonstrate cleavage look like thin slabs stuck together.

Mica breaks in one direction into flat layers, like the pages in a pile of papers. Calcite breaks along three cleavage planes: left and right, front and back, and top and bottom.

Several minerals have unusual properties. Some minerals fluoresce in ultraviolet (UV) light: these minerals absorb UV light, which we cannot see, and emit it as visible light, which we can see. Calcite is a transparent mineral. When you look through it, you see a double image.

Table 1 The Mohs scale of mineral hardness: every mineral will scratch the minerals above it.

Hardness	Mineral
1	Talc
2	Gypsum
3	Calcite
4	Fluorite
5	Apatite
6	Feldspar
7	Quartz
8	Topaz
9	Corundum
10	Diamond

hardness
how easily a mineral can be scratched; measured using the Mohs hardness scale

Figure 3 Mica has one cleavage plane – it breaks into thin sheets of rock.

cleavage
the way a mineral tends to break along particular smooth planes

Figure 4 Calcite is a transparent mineral.

2.2 Check your learning

Remember and understand

1 **Define**:
  a hardness
  b lustre
  c streak
  d cleavage.

2 **Describe** what it means if a mineral has a hardness of 1 on the Mohs scale.

3 **Name** a mineral that has a Mohs hardness of 10.

Apply and analyse

4 **Describe** the lustre of gold.

5 Obsidian has a hardness of 6 on the Mohs scale and was prized by ancient peoples for its sharp edge. **Describe** what type of minerals would damage the sharp edge of an obsidian blade.

6 **Describe** the properties (lustre, hardness, cleavage) of a diamond.

Figure 5 Obsidian

2.3

Minerals are a valuable resource

In this topic, you will learn that:

- minerals are an important source of metals and other materials.
- an ore is a mineral with a large amount of useful metal in it.
- some minerals, such as iron ore, need to be treated before they can be used.

Australia is rich in mineral resources. It is the world's leading producer of lead, bauxite and alumina, diamonds (by volume), ilmenite, rutile and zircon (and synthetic rutile), and tantalum. It is the second largest producer of uranium, zinc and nickel; the third largest producer of iron ore, lignite, silver, manganese and gold; the fourth largest producer of black coal and copper; and the fifth largest producer of aluminium. Worldwide demand for mineral resources is high.

Minerals that contain a large amount of metal are called an **ore** (see examples in Table 1). The metal must be removed or extracted from the ore before it can be used.

Table 1 Important ores and the metals they contain

Ore	Metal
Bauxite	Aluminium
Cassiterite	Tin
Chalcopyrite	Copper
Cinnabar	Mercury
Galena	Lead
Haematite, limonite	Iron
Malachite, azurite	Copper
Molybdenite	Molybdenum
Pentlandite	Nickel
Pitchblende	Uranium
Rutile	Titanium
Sphalerite	Zinc

Figure 1 Coloured sands indicate the concentrations and types of minerals they contain.

Ochre

Ochre is one of the minerals most valued by Aboriginal and Torres Strait Islander peoples. It is prized for its high lustre (sometimes augmented by the addition of crushed mica), which generates a shimmering effect in the light of a fire. Ochre was, and still is, used to cover implements and weapons (axes, spears, boomerangs) and as body paint in ceremonies. Extensively used in rock art, it now features in modern artwork. The ochre is crushed to a fine dust and mixed with fixing agent to make a paste with water, sap, egg, saliva, blood, animal fat and honey. There are six colours of ochre, from yellow to deep orange or brown. Aboriginal and Torres Strait Islander peoples have mined and traded ochre for thousands of years. Wilgie Mia in Western Australia is 20 m underground and is the world's oldest continuous mining operation. Pole scaffolding prevented the mine from collapsing on miners while thousands of rocks were removed to reach the ochre.

Gold

During the 1850s, after gold was discovered in Bathurst, New South Wales, hundreds of thousands of people from across the world migrated to Australia to take part in the Gold Rush in Victoria and New South Wales. During this time, Australia's economy boomed. Gold is chemically stable, so it is almost always found as pure gold. This means that it can be collected without having to be smelted or refined. Gold is used in jewellery, in fine wires in electronics, as fillings for teeth and, because of its reflective properties, to protect satellites and spacecraft from solar radiation.

Mineral sands

Australia is an old continent that is rich in mineral sands. Mineral sands are old beach sands with significant concentrations of heavy minerals, such as rutile, zircon and ilmenite. The ore rutile is a rich source of titanium dioxide, which is used as a pigment in paints, plastics and paper. You may have seen glass jars of mineral sands that are often sold as souvenirs.

EXPERIMENT

2.3: Testing the minerals in toothpaste
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Copper

Copper was the first metal to be used by humans. In Australia, copper is found as the mineral chalcopyrite in rocks that are over 250 million years old. Copper is a good conductor of electricity and is used in electrical generators and motors, for electrical wiring and in electronic goods, such as televisions. Copper is also used for water pipes because it does not corrode easily. It can also be used on surfaces to prevent contamination by microscopic organisms (bacteria and viruses).

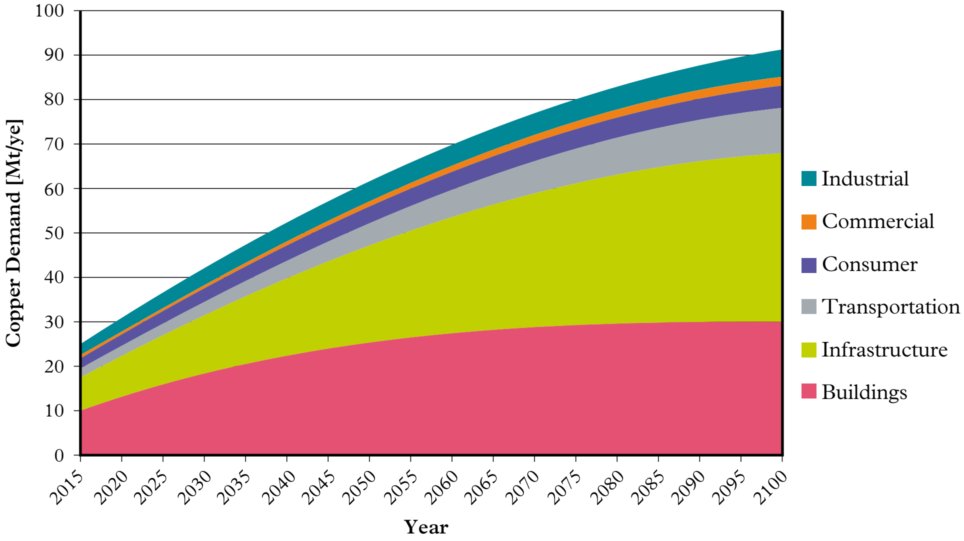

Figure 2 Global demand for mined copper is projected to continue to increase.

Recycling minerals

Earth's mineral resources are finite – they are not renewed. However, they can be recycled. For example, aluminium can be recycled over and over again. A lot of energy is used to produce aluminium from bauxite, but once the metal has been refined it can be recycled indefinitely. Recycling aluminium uses only 5 per cent of the energy needed to produce the same quantity of aluminium from bauxite. So recycling aluminium saves us from having to use coal to produce energy in power stations, which reduces the emission of **greenhouse gases** into our atmosphere.

Mobile phones and minerals

Many electronic devices, such as mobile phones, use the minerals niobium and tantalum. These minerals are found in the ore coltan, which is mined in the Congo River Basin in Africa. Unfortunately, this forest region is also home to endangered gorillas and mining is threatening their habitat.

Recycling the minerals in old mobile phones helps to reduce the impact of mining on the ecosystem in this region.

Figure 3 The minerals in mobile phones can be recycled.

Minerals in toothpaste

Toothpaste contains a variety of minerals that perform different roles when cleaning your teeth. Fluorite (calcium fluoride), found in granite and limestone, makes teeth more resistant to decay. Mica reflects light and is used in toothpaste, paints, roofing and rubber products to make them sparkle. Silica, mined from sand, makes the toothpaste thicker and sodium carbonate is used as a whitening agent.

greenhouse gas
a gas (carbon dioxide, water vapour, methane) in the atmosphere that can absorb heat

2.3 Check your learning

Remember and understand

1 **Define** the term 'mineral'.
2 **Define** the term 'ore'.
3 **Name** two uses for copper.
4 **Identify** five of Australia's most important minerals.

Apply and analyse

5 Use the graph in Figure 2 to **describe** how the global mined copper demand is expected to change after 2042. **Explain** a reason for this change in demand.
6 **Identify** all of the minerals found in toothpaste. **Evaluate** the purpose of each mineral (by explaining the reason each mineral was included and deciding whether it is necessary for the health of the teeth).
7 **Compare** ochre and gold.

Figure 4 Toothpaste contains minerals that help to clean your teeth.

2.4 Igneous rocks develop from magma and lava

In this topic, you will learn that:

- magma (hot liquid rock) flows deep beneath the Earth's surface.
- when the magma moves above the Earth's surface it is called lava.
- igneous rocks form when magma and lava become solid.

igneous rock
rock formed by cooling magma and lava

magma
semiliquid rock beneath the Earth's surface

lava
hot, molten rock that comes to the surface of the Earth in a volcanic eruption

intrusive igneous rock
rock formed underground by slowly cooling magma

extrusive igneous rock
rock formed at the Earth's surface by quickly cooling lava

Rocks are broadly classified according to how they are formed. The three main types of rocks – igneous, sedimentary and metamorphic – form in different ways. **Igneous rocks** form when the magma and lava from volcanic eruptions cool and solidify.

Magma and lava

The term 'igneous' comes from the Latin word *ignis*, which means 'fire'. The hot, molten rock inside the Earth is called **magma** and its temperature can be more than 1200°C. The magma chamber under a volcano is the source of molten rock for the volcano (see Figure 1).

In a volcanic eruption, the red-hot magma rushes out onto the surface of the Earth as **lava**. The cooler conditions at the Earth's surface help to solidify the lava quickly. Igneous rocks also form from magma under the ground. These igneous rocks look quite different from those formed on the Earth's surface because they cool much more slowly.

Intrusive igneous rocks form slowly beneath the surface of the Earth when magma becomes trapped in small pockets. These pockets of magma cool slowly underground (sometimes for millions of years) to form igneous rocks. The longer it takes for lava to cool, the bigger the rock crystals that grow. Intrusive igneous rocks have large crystals locked together. Granite is an intrusive igneous rock in which the crystals can be seen with the naked eye. Although formed underground, intrusive igneous rocks reach the Earth's surface when they are either pushed up by forces in the Earth's crust or uncovered by erosion.

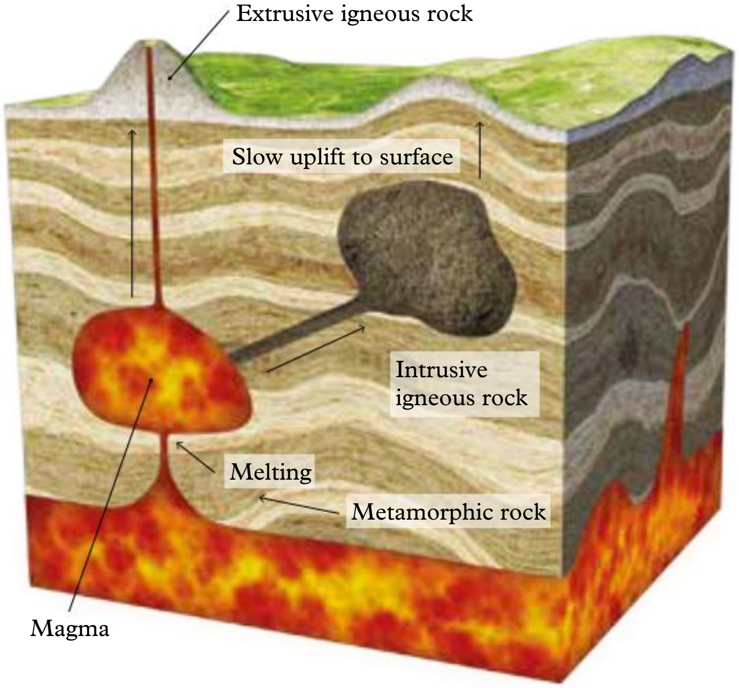

Figure 1 Igneous rocks are formed from volcanic magma.

Extrusive igneous rocks

Lava cools much more quickly on the surface of the Earth. This causes it to form **extrusive igneous rock**. Because the lava is cooling more quickly than the magma underground, the crystals are smaller. Sometimes, the lava cools so quickly that no crystals are formed. For example, pumice has no crystal structure. Pumice forms when hot, gas-filled lava cools very quickly. The many tiny holes in pumice are formed by volcanic gases escaping from the cooling lava (see Figure 3). It has so many holes that it is extremely light and can float on water. Pumice stones are used to scour hard skin from feet, and powdered pumice is found in some abrasive cleaning products.

EXPERIMENT

2.4: What affects crystal size?
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Figure 2 Granite is an intrusive igneous rock.

The different forms of basalt

Magma can solidify into many different igneous rocks, which can vary in appearance. This is because of how igneous rocks form and the minerals they contain.

Basalt is the most common type of rock in the Earth's crust. Most of the crystals in basalt are microscopic or non-existent because the lava cools so quickly that large crystals do not form.

We commonly think of basalt as the building product bluestone. However, basalt can look different depending on the type of volcanic eruption that produced it and how quickly it cooled. Scoria is a type of basalt that is full of bubble holes. The lava was filled with gases when it began to cool and the holes in the scoria are where the gas bubbles once were. Scoria is a light rock that is often used for garden paths and as fill in drainage trenches.

Obsidian is a smooth, black rock that looks like glass. It is formed when lava cools almost instantly and forms no crystals. Obsidian is used to make blades for surgery scalpels; the resulting blades are much sharper than those made from steel.

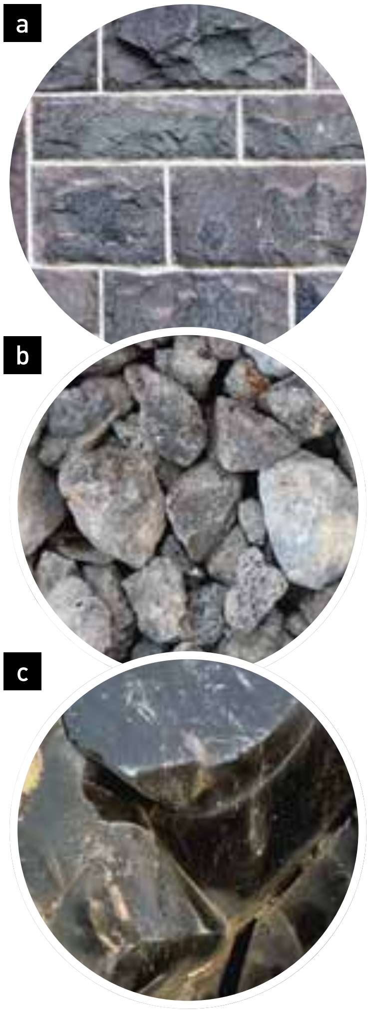


Figure 4 Basalt comes in different forms: **a** bluestone, **b** scoria and **c** obsidian.

Figure 3 Pumice contains many holes that make it light enough to float on water.

2.4 Check your learning

Remember and understand

1 **Define** the term 'igneous'.

2 **Describe** how igneous rocks form.

3 **Identify** the type of rock that is produced by magma that cools deep below the Earth's crust.

4 **Identify** an igneous rock that would float on water.

Apply and analyse

5 The ancient civilisations that discovered obsidian had a competitive advantage over those who didn't. **Explain** a possible advantage of obsidian rock.

6 **Contrast** (the differences between) the properties of intrusive and extrusive igneous rocks.

2.5 Sedimentary rocks are compacted sediments

In this topic, you will learn that:

- sedimentary rocks are formed from compacted particles or sediment.
- sedimentary rocks can contain fossils.
- stalactites and stalagmites are forms of sedimentary rock.

Video 2.5
Sedimentary rocks

sedimentary rock
rock formed from compacted mud, sand or pebbles, or the remains of living things

Sedimentary rocks are formed when loose particles are pressed together (compacted) by the weight of the overlying sediments. Sediments are rock particles such as mud, sand or pebbles, which are usually washed into rivers and eventually deposited on the riverbed or in the sea. Sediments can also come from the remains of living things, such as plants and animals.

Sediment

Over thousands or even millions of years, sediments form thick layers on the riverbed or sea floor. Pressure from the overlying sediments and water forces out air and any gaps in the bottom layer. Over time, the compacted sediments become sedimentary rocks.

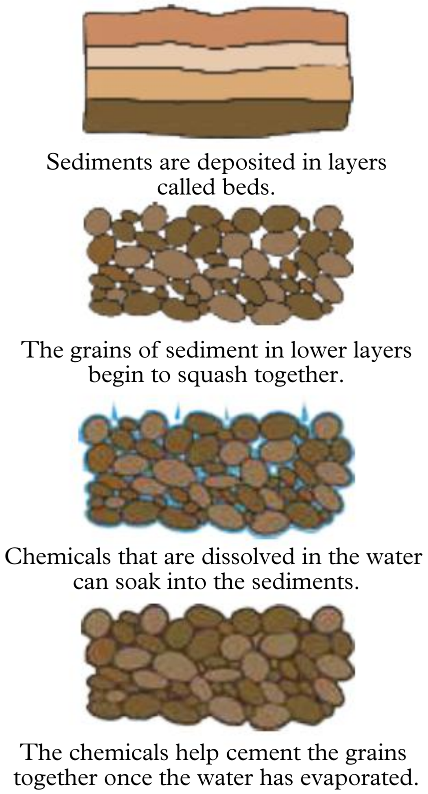
The names of some sedimentary rocks are clues to the sediments that formed them – sandstone, mudstone, siltstone and conglomerate are all types of sedimentary rock. Sandstone is made up of sand deposited in environments such as deserts and beaches. Conglomerate is a mixture of all sizes of rocks that have become cemented together (see Figure 6).

Figure 1 Shale (or mudstone) is the most common sedimentary rock. Shale is a fine-grained sedimentary rock made up of clay minerals or mud.

Biological rocks

Sedimentary rocks are not always formed from the sediments of minerals or other rocks. The remains of living things also break down and are deposited as sediments. Shells and hard parts of sea organisms break down and are deposited in layers on the ocean floor. Eventually, they become cemented together under pressure to form limestone.

The compaction of dead plant material can also help to form sedimentary rocks. For example, coal is formed from dead plants that were buried before they had completely decayed. Compression forces from the layers above can change the plant material into coal or oil.



Sediments are deposited in layers called beds.

The grains of sediment in lower layers begin to squash together.

Chemicals that are dissolved in the water can soak into the sediments.

The chemicals help cement the grains together once the water has evaporated.

Figure 2 The formation of sedimentary rocks

EXPERIMENT

2.5: Making sedimentary rocks
Go to page **178**.

Chemical rocks

Chemical sedimentary rocks form when water evaporates, leaving behind a solid substance. When seabeds or salt lakes, such as Lake Eyre in South Australia, dry up, they leave a solid layer of salt behind. If the layer of salt is compressed under the pressure of other sediments, it may eventually form rock salt.

Limestone caves

When groundwater passes over limestone, it can dissolve calcium carbonate from the limestone. When the water evaporates, it leaves behind the calcium carbonate. Various rock formations in caves are formed by this method.

The amazing long strands of rock found on cave floors and ceilings are composed of calcium carbonate from the limestone ceiling of the cave. A stalagmite grows from the floor towards the ceiling (they 'might' reach the ceiling one day) and a stalactite grows down from the ceiling (they hold on 'tight'). If these formations meet in the middle, then they form a column.

Stalagmites and stalactites form when limestone rocks are dissolved by acids in water. The acid and dissolved limestone form a solution that drips through the ceiling of the cave and is deposited on the stalagmites and stalactites, gradually increasing their width and length. It is important that visitors to limestone caves do not touch the stalactites and stalagmites because they are generally still forming. Oil from skin can interfere with stalagmite and stalactite formation.

Figure 4 Stalagmites and stalactites form in limestone caves.

Figure 3 Sandstone is a popular building material. This ancient temple of Abu Simbel in Egypt was carved directly into the sandstone rock.

Figure 5 Coal is formed from dead plant material.

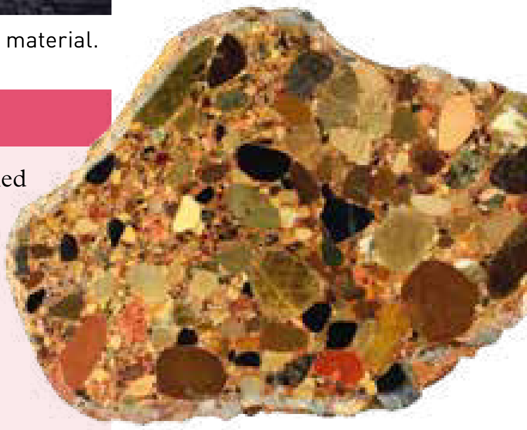


Figure 6 Conglomerate rocks have grains of different sizes.

2.5 Check your learning

Remember and understand

1 **Describe** how sedimentary rocks form.

2 **Describe** how stalactites and stalagmites form.

3 **Describe** how chemical sedimentary rocks form.

Apply and analyse

4 A student claims that sandstone is made up of sand. **Evaluate** their claim (by explaining how sandstone is formed and using this to decide whether the claim is correct).

5 **Explain** the link between plants and coal.

6 **Explain** why sandstone is often used for carving statues.

2.6 Metamorphic rocks require heat and pressure

In this topic, you will learn that:

- rocks deep underground experience high pressure.
- high pressure generates high temperatures.
- high pressures and temperatures cause the rearrangement of minerals to form metamorphic rock.

metamorphic rock	rock formed from other rock due to intense heat and pressure
foliation	layering in a rock that occurs when the rock is subjected to uneven pressure
index mineral	a mineral that only forms at a particular temperature and pressure; used to determine the history of the rock that contains the mineral

Metamorphic rocks are formed when other types of rock are changed by incredible heat and pressure inside the Earth. When igneous, sedimentary or even metamorphic rocks are heated to extreme temperatures by magma, or when they are placed under extreme pressure from the layers of rocks above them, they can change into different types of rock.

Change in appearance

The combination of high temperatures and pressures causes differences in the appearance of metamorphic rocks. (Metamorphism means 'change in form'.) As you go deep underground, the temperature gradually increases. Miners in South Africa's West Wits minefield, who work up to 3.9 km below ground, report temperatures up to 60°C. Temperatures can get much higher anywhere magma intrudes.

The pressure of the earth above the rock also contributes to the different appearance of metamorphic rocks. Bands can occasionally be seen in metamorphic rocks formed under high pressure. If the pressure is uneven, the rock crystals can twist. This is called **foliation**.

Change in minerals

Metamorphic rocks also change chemically. Some metamorphic minerals (sillimanite, kyanite and garnet) only form at high temperatures and pressures. They are called **index minerals** because they can tell us the history of what happened to the minerals – the temperature and pressure they were exposed to. Other minerals, such as quartz, can withstand the high temperatures and pressures and can sometimes be found in metamorphic rocks. The heat and temperature can cause some crystals to change their size and shape. Recrystallisation occurs when the crystals are squeezed together so tightly that they partially melt and form fewer, but larger, crystals. For example, when granite is squeezed under high pressure, the crystals change and the rock gneiss is formed (see Figure 2).

Metamorphic rocks are stronger than the original material because the particles have been fused together under great pressure or heat.

Figure 1 Foliation occurs when rock is subjected to uneven pressure.

EXPERIMENT
2.6: Making a metamorphic rock
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Figure 2 a When granite, an igneous rock, is subjected to high heat or pressure, it can change into the metamorphic rock known as gneiss. **b** The bands on gneiss show that the crystals have been squeezed together under immense pressure.

Figure 3 Slate cleaves easily into flat sheets because of its flat, parallel crystal structure. This makes it a useful material for floor and roof tiles and the base of billiard tables.

Figure 4 The Taj Mahal in India is made of marble, the metamorphosed form of limestone. With its dense composition and beautiful patterns, marble is also a popular material for sculptures and kitchen benchtops.

Check your learning 2.6

Remember and understand

1 **Describe** where metamorphic rocks are formed.
2 **Describe** how metamorphic rocks are formed.
3 **Describe** a foliated rock.

Apply and analyse

4 **Explain** why slate is useful for floor tiling.
5 A student claimed that a rock had to be igneous because it had quartz crystals. **Evaluate** their claim (by explaining how quartz crystals are formed and using this to decide whether the claim is correct).
6 **Identify** which type of rock is stronger: sandstone or marble. **Justify** your answer (by explaining how each rock is formed, linking this to their properties and deciding which is stronger).

2.7

The rock cycle causes rocks to be re-formed

In this topic, you will learn that:

- weathering is the breaking down of rocks and minerals through the movement of water and animals, and the extremes of temperature.
- erosion is the movement of the sediment to another area.
- the rock cycle describes the formation of sediment, sedimentary rock, compression to metamorphic rock and melting and solidification to form metamorphic rock.

Video 2.7
What is the rock cycle?

rock cycle	the process of formation and destruction of different rock types
onion-skin weathering	weathering of rock where the outside of the rock peels off
tor	a large, round rock produced by onion-skin weathering
frost shattering	a process of weathering in which repeated freezing and melting of water expands cracks in rocks, so that eventually part of the rock splits off

The **rock cycle** is an ongoing process that describes the formation and destruction of the different rock types.

Physical weathering

Mechanical, or physical, weathering occurs when a physical force is applied to a rock. It includes the breakdown of rocks by non-living things.

In desert areas, the days are very hot and the nights are freezing cold. This daily heating and cooling affects only the outside of the rock. This is because rocks do not conduct heat very well. Sometimes the outside of the rock can peel off, just like an onion skin. This process is called **onion-skin weathering** and the round rocks produced in this way are called **tors**.

When water freezes at night, it expands and takes up more space. When water freezes in the crack of a rock, it expands and pushes hard against the rock around it. This can make the crack larger. When the ice melts during the warmer day, water fills the crack again. The next night, ice forms again and makes the crack even larger. This process is repeated many times until part of the rock is split off. This process is called **frost shattering**.

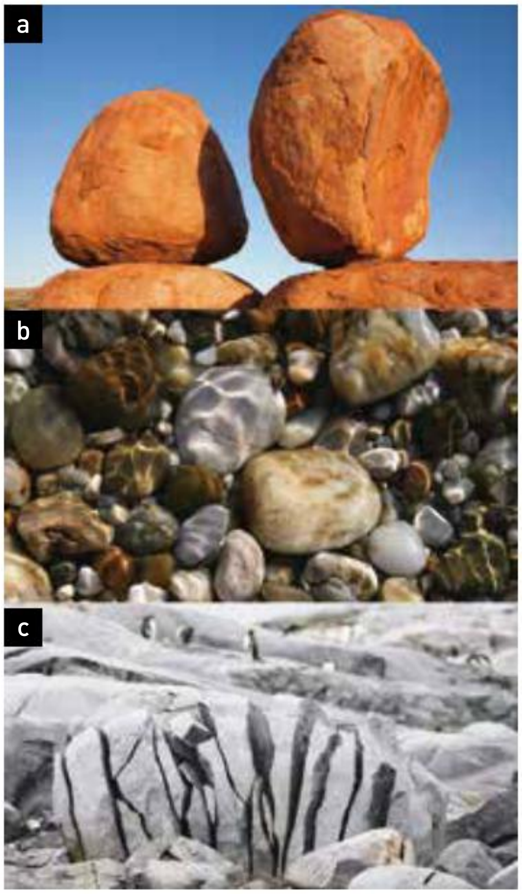
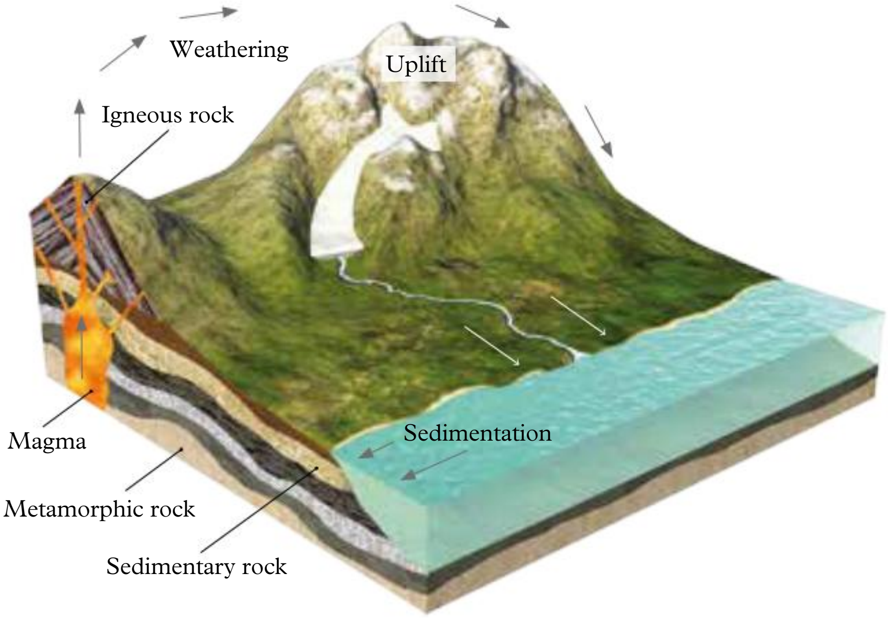


Figure 2 Physical weathering can include **a** onion-skin weathering, **b** wearing away by water (abrasion) and **c** frost shattering.

Figure 1 The rock cycle



SKILLS LAB

2.7: Modelling the rock cycle
Go to page **180**.

Chemical weathering

Chemical weathering changes the minerals in rocks. Carbon dioxide in the air mixes with the water to form a weak acid rain (a much weaker acid than vinegar). When the acid rain falls on rocks such as limestone, a chemical reaction changes the minerals in the rock and the minerals are washed way (eroded). You can see evidence of this type of weathering in old statues.

Biological weathering

Biological weathering can start with a seed falling into a crack in the rock. Soil and water in the rock encourages the seed to grow. As the roots grow, they push on the cracks in the rock, eventually causing the rock to break.

Over time, the large rocks are broken down into smaller rocks, which are broken down into sediment. This process is called weathering. The sediment is eroded and carried by wind and water to an area where it accumulates. Gradually, the sediment becomes buried under many layers, re-forming as sedimentary rock.

Heat and pressure

As more layers form on top of the sedimentary rock, it is put under pressure. Over time, the layers sink deeper to where the temperatures start increasing. Increased temperature and pressure cause physical and chemical changes in the rock, transforming it into metamorphic rock. If the temperature continues to rise, the rock will melt, turning it into its liquid form, magma.

Magma is also put under great pressure, causing it to seek any available space. Gradually it makes its way to the surface where it can cool as igneous rock. Over time, it is exposed to wind and water. The cycle continues.

Figure 3 Chemical weathering can be caused by acid rain.

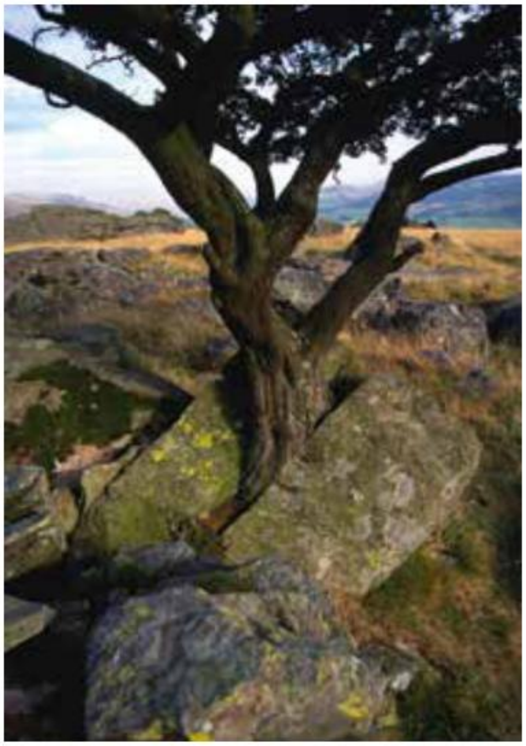


Figure 4 Biological weathering can be caused by plant roots.

Figure 5 The rock cycle can lead to rocks being smoothed.

2.7 Check your learning

Remember and understand

1 **Describe** how tors are formed.

2 **Describe** the process of frost shattering.

Apply and analyse

3 **Compare** (the similarities and differences between) biological and chemical weathering.

4 **Contrast** (the differences between) weathering and erosion.

5 **Describe** the different stages in the rock cycle. Use the rock cycle diagram in Figure 1 to assist you.

Evaluate and create

6 Write a creative story of the 'life of a rock'. Rocks change with time, as do humans. However, unlike humans, rocks are never truly 'born', nor do they 'die' – they can move through the rock cycle, covering the same stage many times in many different ways. **Describe** the life that your rock experiences.

2.8 Weathering and erosion can be prevented

In this topic, you will learn that:

- humans can impact weathering and erosion.
- understanding how weathering and erosion occurs allows us to prevent it.
- engineers design solutions to erosion.

Humans are very good at changing their environment to suit their needs. However, this has changed the rate of rock weathering and erosion. This has resulted in flooding and poor food production. Soil erosion engineers are helping to solve this problem.

Figure 1 Footpaths, roads and roofs affect how water moves around the land.

Preventing erosion

The population of Australia has been steadily increasing for many years and as a result we have needed to build more houses and grow more food. Building houses means building roads and footpaths around the houses. Instead of trees and grasses lining a riverbank, footpaths and roads can be built right up to the edge of the water flow.

The roots of plants interlace with other roots and the soil, helping the soil resist the movement of wind and rain. If plants are removed, then the topsoil will erode.

Rain falling on concrete paths and roads is not absorbed into the soil. Instead, it flows off the road and carries away further soil layers. This can slowly remove the support beneath the built structures, causing them to collapse. The loose soil and rocks can trigger damaging mudslides. Engineers are responsible for developing ways to solve this problem.

Figure 2 Australia's population has increased dramatically since the beginning of the twentieth century.

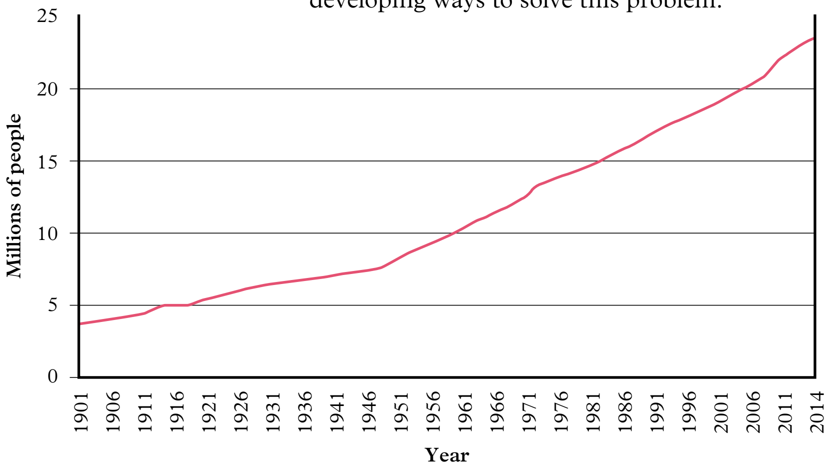


Figure 3 Soil erosion can lead to landslides that affect footpaths, houses and roads, endangering people's lives.

CHALLENGE
2.8: Preventing soil erosion
Go to page 181.

Engineering solutions

Figures 4–9 show some solutions to weathering and erosion.

Figure 4 Engineers try to minimise erosion by controlling the flow of water with dams and levees.

Figure 5 Groynes are built on beaches to remove some of the energy of the waves. They protrude from the beach and trap the sand, preventing its erosion.

Figure 6 Terraces may be built to allow water to follow a set path that is protected from erosion by man-made structures such as drains, or by plants. This reduces the force of the water, making it less likely to cause damage.

Figure 7 New products have been developed that allow water to move through them instead of becoming run-off. This allows the water to be absorbed into the soil and join the groundwater.

Figure 8 Temperature erosion causes materials such as concrete to crack. Footpaths have grooves in them to allow for their expansion during hot weather.

Figure 9 Regular cleaning prevents the build-up of moss and pollution that might contribute to biological or chemical erosion.

2.8 Check your learning

Remember and understand

1 **Explain** the purpose of a groyne.

2 **Identify** two ways erosion can affect food production.

3 **Explain** what a soil engineer does.

Apply and analyse

4 **Contrast** weathering and erosion.

5 **Describe** how an engineer could prevent water from eroding soil.

6 Find an area near your school that has been affected by erosion. Suggest a way that you could prevent further erosion.

//SCIENCE AS
A HUMAN ENDEAVOUR//

2.9 The location and extraction of minerals relies on scientists

Geologists are scientists who study the rocks and particles that make up the Earth and the rocks that were formed. As part of this study they produce and use geological maps using geophysical methods such as seismic testing, magnetometer testing, electromagnetic testing and gravimetric testing. Geochemistry involves the use of chemistry principles to identify the location and type of minerals in the earth.

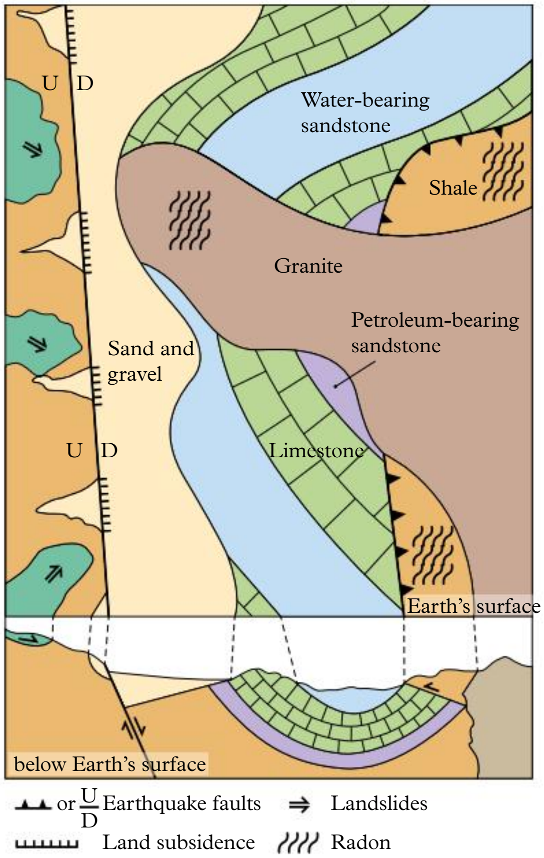


Figure 1 Geological maps allow geologists to determine the location of mineral resources that could be extracted.

seismic geophysical testing
the collecting of geophysical data such as differences in magnetic fields and gravity fields between different geological locations

Geological mapping

Geological maps show all the rocks and minerals in an area. These maps are a representation of the types of rock found under the surface of the Earth. Different colours or symbols are used to indicate the types of rock found at each location.

These maps can be used to locate ground water, identify possible contamination risks, predict earthquakes or volcanic eruptions and identify energy and mineral resources and the costs of mining them.

They can be constructed in different ways. Most are a result of geophysical and geochemical testing.

Geophysical testing

Geophysical testing involves the testing of the physical properties of the earth and the atmosphere. This may include oceanography (the study of the ocean), seismology (the study of earthquakes), volcanology (the study of volcanoes) and geomagnetism (the study of the Earth's magnetic field).

Seismic geophysical testing involves sending vibrations into the earth. The vibrations move differently in different types of rock. The vibrations often bounce off the different layers of rock and travel back to the surface. Special microphones called geophones are spread across the surface of the Earth. These geophones record the returning vibrations and a computer uses the data to construct a 3D map.

EXPERIMENT
2.9: Copper treasure hunt
Go to page **182**.

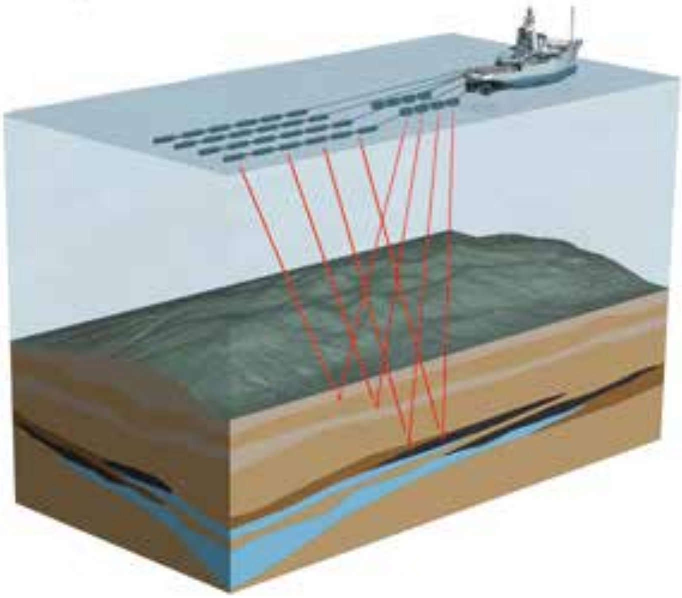


Figure 2 Seismic refraction method

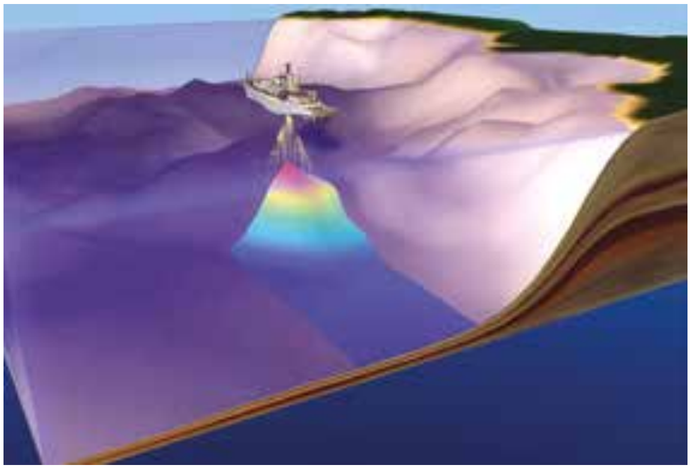


Figure 3 Oceanography boat

Oceanography boats will often carry out geophysical surveys to locate geological structures on the ocean floor.

The presence of some metals beneath the Earth's surface can cause small changes in the Earth's magnetic field. These small changes can be picked up by **magnetometers**.

Electromagnetic pulses can be sent into the soil to detect different types of minerals. Some rocks contain minerals that do not conduct electricity, whereas others are affected by the electromagnetic signal. This change is detected by specialised meters carried by the geophysicist.

The gravity of the Earth is not constant. Small changes are caused by the density of the rock under you. You would not be able to pick up these variations in gravity; however, they can be detected by a **gravimeter**. For large-scale surveys, helicopters carrying gravimeters fly in grid patterns across the surface of the Earth.

magnetometer
a device that detects the difference in magnetic field between one location and the next

electromagnetic
relating to the physical interaction between moving charged particles and the magnetic field that is created as a result

gravimeter
a device that measures the difference in gravity between one location and the next

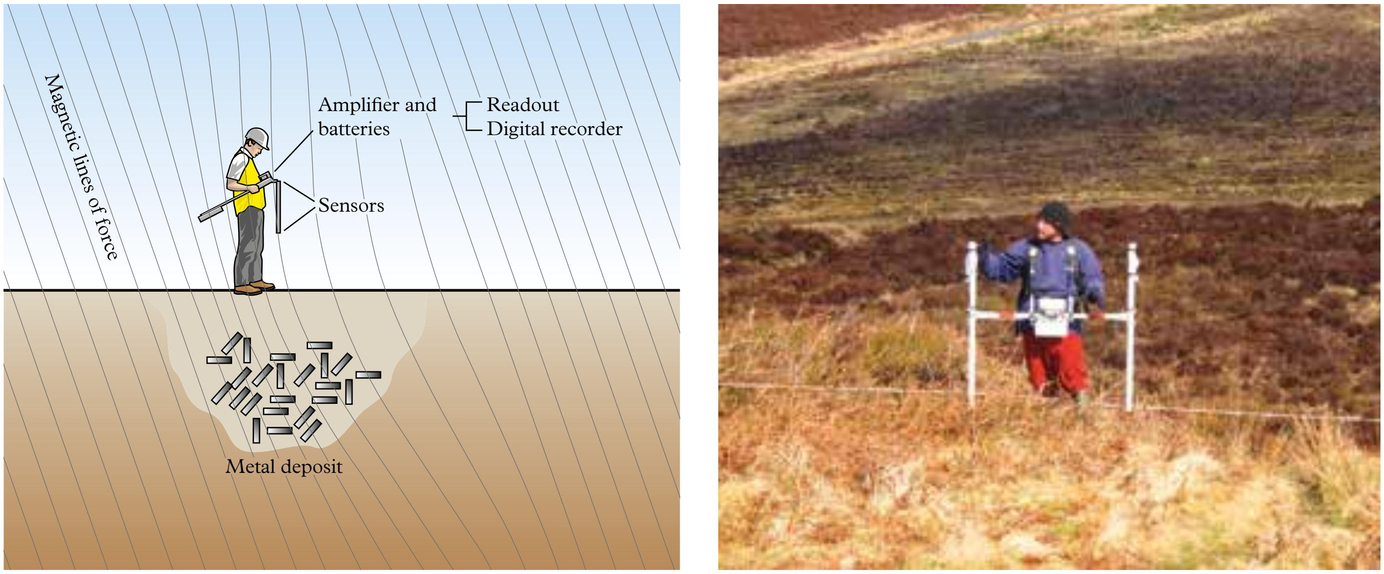


Figure 4 Person walking across the Earth's surface with a magnetometer

Geochemical testing

Geochemical analysis is used to determine what chemicals or minerals are in the rocks. It can be used to detect the presence of petroleum products, metals and commercially valuable minerals. It can be a bit like a treasure hunt. Small samples of sediment or rocks are collected at a number of different sites and are taken back to a laboratory for chemical tests. Some samples might show a higher than normal level of a mineral such as copper. The geochemist will then go back to the site where those samples were located, and do further tests to locate the source of the copper.

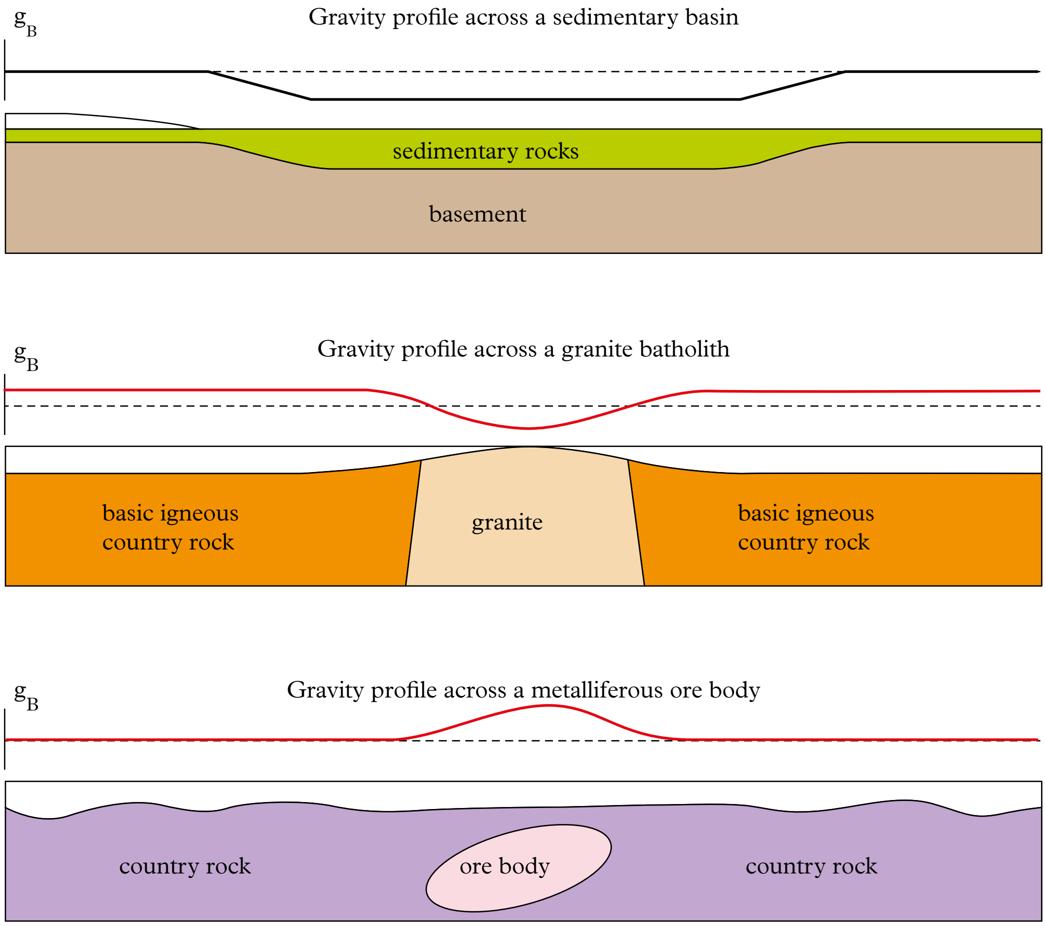


Figure 5 Granite and sedimentary rocks have lower gravitational fields than metal ores.

Figure 6 Helicopter with a front-end gravimeter

Extracting the minerals

Extracting the minerals can be very expensive. If the mineral is close to the surface, open mining may be used. This involves removing the surface of the soil, so that the mineral can be easily extracted and taken for processing. If the mineral is deep under the Earth's surface, sub-surface mining – where tunnels or shafts are used to reach the mineral deposits – may be used. Geologists will often prepare reports on the costs of mining the mineral. This will then be compared to the amount of money expected to be made from selling the mineral. If the cost of mining is less than the expected value of the mineral, the extraction will begin.

2.9 Develop your abilities

Evaluating the importance of land use

The amount of land available for use is limited. This can cause ethical conflict between the needs of different groups in the community, including:

a mining resources

b food production

c housing

d conservation of native plants and animals.

For each of the groups above:

1 **Describe** one reason why their need of an area of land may be important.

2 **Describe** how the use of land in this way could affect your life in a positive way and therefore be important to you.

3 **Evaluate** which of the four uses of the land is most important by determining which of the reasons is most significant to you and explaining why you made this decision.

4 **Consider:** if this group wanted to use the land surrounding your house, describe how this would change the way you live. **Describe** whether this changes the decision you made in step 3. **Explain** your reasoning.

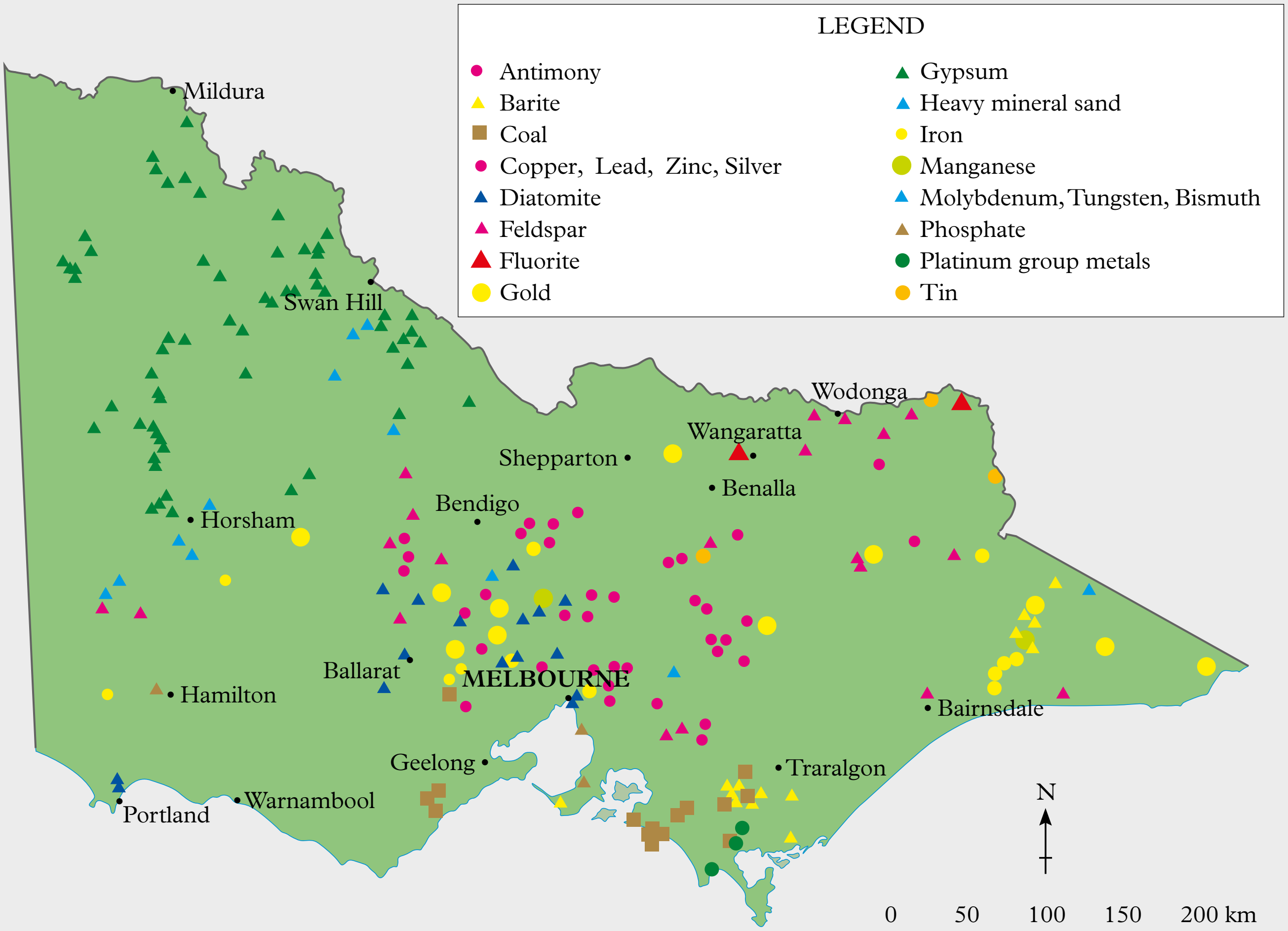


Figure 7 Geolocation has identified many different minerals across Victoria.

REVIEW 2

Multiple choice questions

1 Fossils usually form:
  - **A** in layers of sediment
  - **B** in layers of igneous rock
  - **C** as wind erodes layers of rock
  - **D** as water erodes layers of rock.

2 **Identify** the rock type that is formed from lava.
  - **A** sedimentary rock
  - **B** metamorphic rock
  - **C** igneous rock
  - **D** marble rock

3 The term used to identify the ability of one rock to scratch another is:
  - **A** lustre
  - **B** hardness
  - **C** cleavage
  - **D** streak.

Short answer questions

Remember and understand

4 Copy and complete the following sentences.
  - **a** An ________________ is a mineral with a large amount of useful metal in it.
  - **b** ________________ rocks are formed when loose particles are pressed together by the weight of overlying sediments.
  - **c** ________________ rocks are formed when other types of rocks are changed by heat and pressure inside the Earth.
  - **d** ________________ rocks form when magma and lava from volcanic eruptions cool and solidify.

5 **Define**:
  - **a** lustre
  - **b** streak
  - **c** hardness.

Figure 1 Boulder opals have an ironstone backing that increases their hardness.

6 **Contrast** magma and lava.

7 **Describe** how geologists identify minerals.

8 **Explain** why colour is not a reliable guide for identifying minerals.

9 **Describe** the properties of gold that made it valuable to early civilisations, such as the Incas of South America.

Figure 2 Gold is found throughout Australia.

10 **Describe** the properties that would allow you to determine the difference between intrusive and extrusive igneous rocks.

11 Cave systems in limestone rock follow the course of underground rivers. **Explain** why water is necessary to form caves.

12 **Explain** why only simple fossils are found in the oldest types of rocks, whereas younger rocks have fossils of mammals.

13 Design a flow chart of how fossils are formed.

Apply and analyse

14 Use Table 1 from Topic 2.1 to **identify** the following rocks based on their properties.
  - **a** a fine grain and no hardness, dark in colour
  - **b** density of 2.2–2.8, light colour, course grain size and hard
  - **c** fine grain size, soft, dark in colour

15 **Describe** how sedimentary rocks form at the Earth's surface.

16 **Explain** why pumice has no crystal structure even though it is a rock.

17 **Contrast** the different ways a rock can undergo weathering.

18 **Describe** how the different rock formations (stalactites, stalagmites and columns) found in a cave are formed.

19 **Compare** diamond and graphite.

20 **a** **Identify** the predicted global demand of mined copper in 2072.
  - **b** **Identify** the global demand of mined copper in 2032.
  - **c** **Calculate** how much demand is predicted to increase between 2032 and 2072.

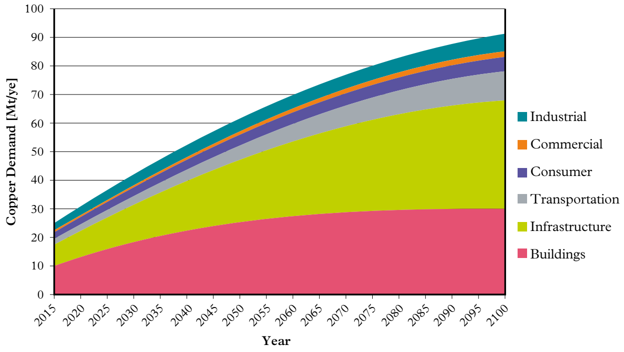


Figure 3 Global demand for mined copper is projected to continue to increase.

Evaluate

21 **Explain** what types of rocks you would look for if you were a palaeontologist searching for fossils.

22 **Explain** why kitchen scourers that can be used to clean stainless steel cutlery should not be used to clean silver-plated cutlery.

23 **Identify** two minerals that can be recycled and the products they could produce.

24 Some famous works of art are made of marble. **Describe** the properties of marble that make it ideal for sculpture. **Identify** some properties of marble that may not make it appropriate for all works of art.

25 Victoria has no active volcanoes, but there are still examples of igneous rocks throughout the state. Suggest what this implies about the history of volcanic activity in Victoria.

Social and ethical thinking

26 Some people say that Australia is a huge quarry. This is because Australia mines so many minerals and sells them. Working on your own, list the advantages and disadvantages of mining and selling minerals. Join with a classmate and combine your lists. Then join with another group and prepare another list containing the three best reasons for mining and the three best reasons against mining.

Critical and creative thinking

27 Figure 4 shows the Twelve Apostles found along the Victorian coast. Use this image to describe how these rocks were formed. Prepare a poster to show how the rocks were formed and would have changed over time. **Describe** how they may change over the next 1000 years.

Figure 4 The Twelve Apostles are located off the coast of Victoria.

28 Imagine you are a geologist who is going to discover minerals in a remote part of Australia. You will need to take a test kit to help you identify the minerals you find. **Describe** the items that should go into your kit to allow you to test for streak, hardness and so on.

29 Victoria, New South Wales and Queensland are susceptible to flood waters that can cause quick erosion. Based on the engineering solutions from Topic 2.8, suggest what towns in flood-prone areas could do to protect themselves.

Research

30 Choose one of the following topics for a research project. Some questions have been included to help you begin your research. Present your report in a format of your own choosing.

» Formation of oil

Oil is formed from the compression of dead marine-plant material in mud over millions of years. Oil is made up of hydrocarbons, which are lighter than rock and water, so it often migrates up through porous rock towards the Earth's surface.

- Describe an oil reservoir.
- Describe the conditions that are needed for an oil reservoir to form.
- Describe how an oil field is formed.

» Gemstones

- Identify which gemstones are found in Australia.
- Identify which gemstones are dug up by recreational fossickers.
- Describe what the gemstones look like.

» Extraction of metals

Metals are extracted from ore using a variety of methods. Some are heated, some are purified using electrical energy, and some are extracted using chemical processes. Describe why different metals are extracted using different chemical or electrical processes. Find out how some metals are extracted, such as copper and aluminium, and design a poster that shows the process of extraction.

Reflect

The table below outlines a list of things you should be able to do by the end of Chapter 2 ‘Rocks and minerals’. Once you’ve completed the chapter, use the table to reflect on your ability to complete each task.

	I can do this.	I cannot do this yet.
Define properties, geologist and geology. Provide examples of some rock properties. Explain the difference between fine, medium and course rock grains.	☐	☐ Go back to Topic 2.1 ‘Rocks have different properties’ Page 18
Define mineral, lustre, streak, hardness and cleavage and describe a rock sample in these terms. Explain how to test a rock sample for hardness and streak. Demonstrate techniques to test a rock sample for lustre and hardness.	☐	☐ Go back to Topic 2.2 ‘Rocks are made up of minerals’ Page 20
Define ore and list some common ores and their minerals. Identify mineral ores as non-renewable resources. Relate the properties of minerals to their uses.	☐	☐ Go back to Topic 2.3 ‘Minerals are a valuable resource’ Page 22
Define igneous rock, magma, lava, intrusive igneous rock and extrusive igneous rock. Describe the differences between magma and lava, and intrusive and extrusive igneous rock. Relate the differences in structure and appearances of intrusive and extrusive igneous rock with the way in which they are formed.	☐	☐ Go back to Topic 2.4 ‘Igneous rocks develop from magma and lava’ Page 24
Define sediment and sedimentary rock. Describe the process of sedimentary rock formation. Explain the difference between biological and chemical rocks.	☐	☐ Go back to Topic 2.5 ‘Sedimentary rocks are compacted sediments’ Page 26
Define metamorphic rock, foliation and index mineral. Describe the process of metamorphic rock formation. Explain why metamorphic rocks are stronger than the original material.	☐	☐ Go back to Topic 2.6 ‘Metamorphic rocks require heat and pressure’ Page 28
Define the rock cycle, weathering, erosion, onion-skin weathering and frost shattering. Describe the differences between physical, chemical and biological weathering.	☐	☐ Go back to Topic 2.7 ‘The rock cycle causes rocks to be re-formed’ Page 30
Describe the role of soil erosion. Provide examples of solutions to reduce or prevent soil erosion.	☐	☐ Go back to Topic 2.8 ‘Weathering and erosion can be prevented’ Page 32
Identify the geophysical and geochemical methods used to locate minerals within the Earth. Describe the costs and benefits associated with mineral extraction.	☐	☐ Go back to Topic 2.9 ‘Science as a human endeavour: The location and extraction of minerals relies on scientists’ Page 34

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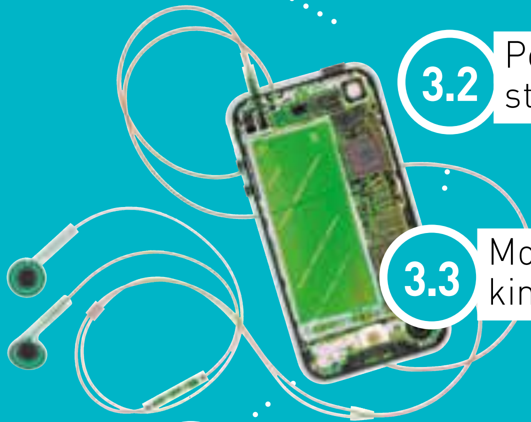
CHAPTER 3

ENERGY

What is energy?

3.1 Energy can be transferred



3.2 Potential energy is stored energy

3.3 Moving objects have kinetic energy

3.4 Energy can be transformed

3.5 Energy cannot be created or destroyed

3.6 Energy efficiency can reduce energy consumption

3.7 Science as a human endeavour: Engineers use their understanding of energy to solve problems

3.8 Science as a human endeavour: Solar cells transform the Sun's light energy into electrical energy

What if?

Rolling cars

What you need:

Ramp, permanent marker, large toy car, tape measure, weights, Blu Tack

What to do:

1 Set the ramp up on the floor so it is at an angle.
2 Draw a starting line at the top of the ramp.
3 Place the large toy car on the starting line.
4 Release the car.
5 Measure how far the car rolls from the bottom of the ramp.

What if?

» What if weight was added to the car? Would it roll further?
» What if the ramp was placed at a different angle?
» What if the ramp was longer?

3.1

Energy can be transferred

In this topic, you will learn that:

- energy is the ability to do work. It is how things change and move.
- energy cannot be created or destroyed.
- when energy is passed from one object to another, it is said to be transferred.

transferred
describes energy that has moved from one object to another

All objects have energy (including moving objects, stretched objects and objects high off the ground). It is energy that gives objects the ability to change or move. Energy cannot be created or destroyed. Instead, it is passed (**transferred**) from one object to another. Most of the energy that exists around us comes from the Sun.

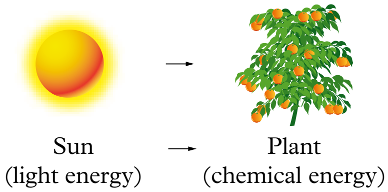


Figure 1 Plants use energy to grow.

The flow of energy

We have all felt the energy of the Sun on a hot day. It can warm our skin and even cause sunburn. Plants are very efficient at absorbing the energy of the Sun. The energy is transferred from the Sun to the plant. This can be shown using a flow diagram (see Figure 1) where an arrow shows the direction of energy flow.

The plant uses the energy to grow. Eventually animals (including us) eat the plants and the energy is transferred again (see Figure 2).

We use the energy for moving, including walking. This also produces heat that then warms up the air around us (see Figure 4).

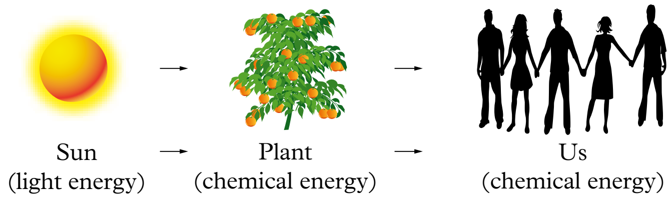


Figure 2 We use the energy from plants to move.

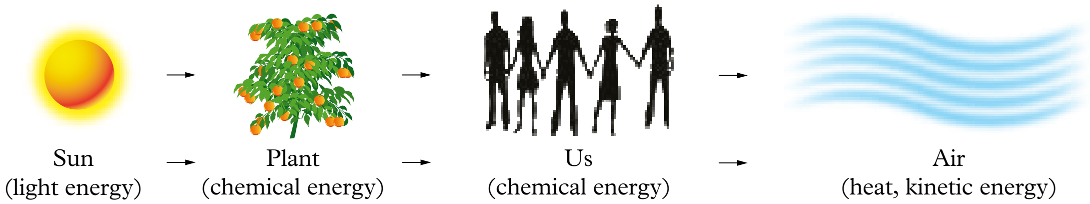


Figure 3 Heat energy warms up air.

Figure 4 We use energy to walk and carry things.

SKILLS LAB
3.1: Draw flow diagrams of energy transfer
Go to page **183**.

Energy transfers for movement

Electric cars are being designed to use the energy stored in batteries, rather than petrol, to power an electric motor that makes the wheels turn. This can be shown using a flow diagram (see Figure 6).

Public transport uses energy too. Trams and metropolitan trains transfer the electrical energy from overhead wires into the motor that makes the wheels move (see Figure 7).

Trains that travel to country areas or interstate usually run on diesel fuel and don't need overhead electrical wires. The engines in these trains burn diesel fuel, transferring the energy into wheel movement via the motors (see Figure 8). Ships and planes use a similar process in their engines.

Figure 5 Hybrid cars use both a petrol engine and an electric motor to send power to the wheels.

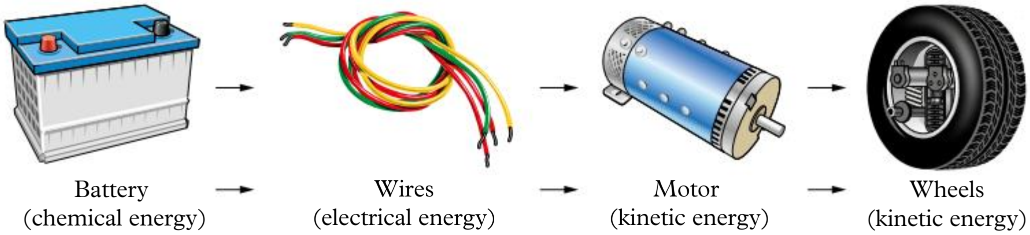


Figure 6 Chemical energy from a battery is used to turn the wheels of a car.

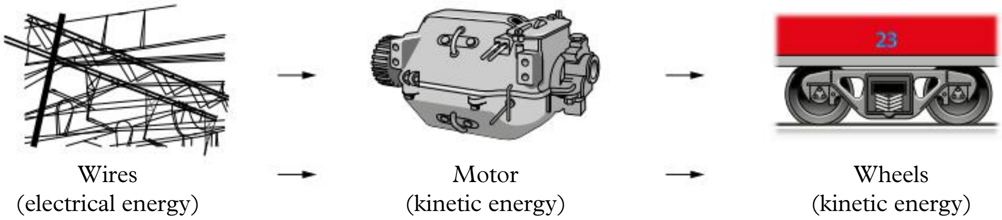


Figure 7 Electrical energy from wires is used to move the wheels of some trains.

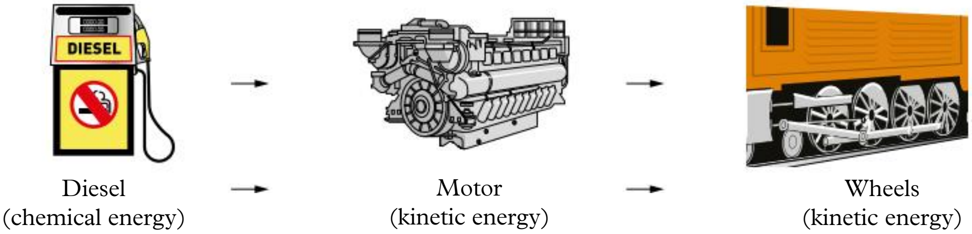


Figure 8 Chemical energy from diesel fuel is used to move the wheels of some trains.

Figure 9 Powerlines provide electrical energy for public transport.

Figure 10 Aircraft use higher-quality fuels than road transport vehicles to minimise weight and waste.

Figure 11 Powerlines are not practical in rural areas, so diesel fuel is used.

Energy transfers for entertainment

A mobile phone uses a speaker to produce the sound of a person's voice or the various ring tones and beeps that the phone makes. Home phones use a speaker too, as do CD systems, headphones, radios and many other devices. They all transfer energy from a battery to the wires inside the speaker, then the energy is transferred to the speaker to make sound.

remote control
an electronic device used to operate a machine remotely (i.e. at a distance)

A television **remote control** transfers energy from the device through the air as light energy, and into the television set (see Figure 14). In fact, most remote controls use infrared light, which is the invisible type of light usually associated with heat. The remote control sends a pulse of infrared light that represents a particular command, such as changing the channel or increasing the volume. An infrared light detector on the television receives the light signal and transfers it back into electrical energy, which then carries out the command.

Figure 12 Headphones transfer energy in batteries to our ears as sound.

Figure 13 The internal components of a mobile device

Figure 14 A television remote control uses an infrared light-emitting diode (LED) to operate the television.

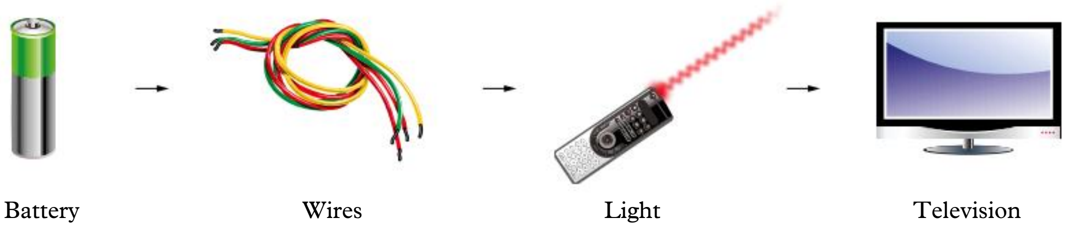


Figure 15 Television remote controls use infrared lights to carry out commands.

3.1 Check your learning

Remember and understand

1 **Define** the term ‘energy’.

2 **Identify** the type of devices that the following flow diagrams could represent.
   - a wires → motor → air
   - b battery → wires → light globe
   - c Sun → muscles → bicycle

3 **Summarise** the entertainment devices mentioned in this topic and draw flow diagrams for the energy transformations they perform.

4 Copy Figure 16 and label each stage in the flow diagram.

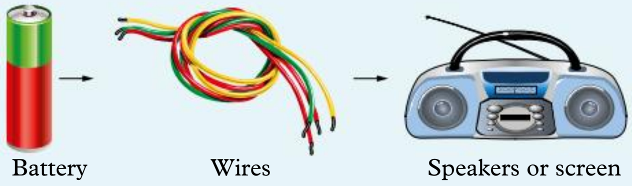


Figure 16 Flow diagram

Apply and analyse

5 **Explain** why the direction the arrows point in a flow diagram is important.

6 **Explain** why country trains mostly use diesel instead of electrical wires.

7 **Identify** the ultimate source of all energy.

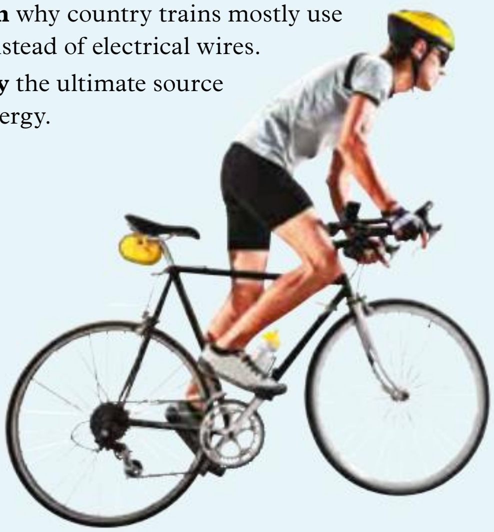


Figure 17 Pedal power

3.2 Potential energy is stored energy

In this topic, you will learn that:

- an object that has the potential (future ability) to do work has potential energy.
- gravitational potential energy is transformed when an object falls.
- elastic potential energy is transferred when an object returns to its preferred shape.
- chemical potential energy is transferred when new chemicals are formed.
- nuclear potential energy is released when an atom is split.

Figure 1 Jumping stilts rely on elastic potential energy.

elastic potential energy the energy possessed by stretched or compressed objects

gravitational potential energy the energy possessed by an object raised to a height in a gravitational field

Elastic potential energy

A trampoline has the ability to 'store' energy, or hold it, for later use or if things change. The springs and the mat of the trampoline stretch under our weight and hold this stored energy. The more they stretch, the more energy they hold. The energy is returned to our bodies when the springs and mat return to normal and throw us into the air. Energy that is stored through stretching or squashing is called **elastic potential energy**.

Gravitational potential energy

If we lift an object up to a height, it gains **gravitational potential energy** (abbreviated to 'GPE').

Figure 2 This television has GPE when raised above the ground.

The larger the mass and the larger the height, the more GPE the object gains. Have you ever noticed that falling a greater distance produces a greater 'thud' and can hurt more? This is because of the amount of GPE. As an object falls down, the object's GPE can be transformed into other forms of energy. This happens when a person plays on a slide at the playground. The higher they climb, the more GPE they get. When they slide down, the GPE decreases. The person gains movement energy. They may also feel the friction of the slide as heat or even as a zap of static electrical energy.

Chemical potential energy

After we have done a lot of exercise, we often crave foods that we believe will restore our energy levels. These foods, usually sweet things, release stored chemical energy really quickly to satisfy our cravings. All foods have some energy stored in them, but

Figure 3 Energy drinks contain chemical potential energy.

EXPERIMENT

3.2: What if the amount of elastic potential energy was increased?
Go to page **185**.

the difference is how quickly the energy can be released.

Fuels, such as natural gas and petrol, provide us with energy too. A Bunsen burner uses the burning of natural gas to provide heat for laboratory experiments. Petrol has chemical energy stored in it, as do explosives and batteries.

These devices all contain chemical potential energy that can be released when we need it. Some batteries can be recharged – the **chemical potential energy** (CPE) can be replaced.

Nuclear energy

Although nuclear energy is used throughout the world, it is not used in Australia. **Nuclear energy** involves the reaction at the centre of atoms. When atoms react in chemical reactions, they usually release only small amounts of energy. However, if the centres or nuclei of those atoms can be made to react, the amount of energy released is much, much larger. In fact, the amount of energy released is so huge that it can cause massive amounts of destruction.

nuclear energy
energy stored in the nucleus of an atom and released in nuclear reactors or explosions of nuclear weapons; much greater than the chemical energy released in chemical reactions

chemical potential energy
energy stored in chemicals, e.g. in food, fuel or explosives; also known as chemical energy

Figure 4 Plastic slides are great at zapping us with static electricity, although it depends on the weather and the clothes we wear.

Figure 5 The energy released from a nuclear explosion is much, much greater than that from other types of explosions.

3.2 Check your learning

Remember and understand

1 **Define** the term ‘potential energy’.

2 List four examples of devices or situations that involve potential energy.

3 **Identify** the type of energy that is stored in a battery.

4 We get our energy from the chemicals in food. **Identify** the type of energy found in food.

5 Biofuel is an alternative source of energy that comes from burning to release the energy stored in plants. **Identify** the type of potential energy released in biofuel.

6 **Describe** four devices, other than those mentioned already, that can be given elastic potential energy.

Apply and analyse

7 **Describe** how a person might use a bow to shoot an arrow. **Identify** the type of potential energy used in this process.

3.3 Moving objects have kinetic energy

In this topic, you will learn that:

- kinetic energy is the energy found in a moving object.
- moving heavy objects have more kinetic energy than moving light objects when they move at the same speed.
- the faster an object moves, the more kinetic energy it has.

Figure 1 Kerosene lamps were used for many years before the invention of electricity.

solar cell
a device that transforms sunlight directly into electrical energy; is usually in the form of a panel; also known as a solar panel

The energy of movement is more scientifically called kinetic energy (KE). Whenever objects or people move, they have kinetic energy. It takes energy to force an object such as a car to start moving. Once it is moving, the energy has passed to the car. It is this energy that is called kinetic energy. The faster the object is moving, or the more mass the object has, the greater the kinetic energy. Even objects too small to be seen can have kinetic energy.

Light energy

Light energy is essential to our lives, and people have invented lots of devices to help us see in the dark, including oil, kerosene and gas lamps. The humble electric light bulb revolutionised the world and led to easily portable light sources such as torches. But the best source of light is, of course, our Sun.

Light energy is one type of energy that our eyes can usually detect. It moves in small packets of energy called photons. We see a range of colours (red, orange, yellow, green, blue and violet) in the visible spectrum, but the light we see is part of a larger group that is called electromagnetic radiation. This large group includes, but is not limited to, ultraviolet light, microwaves and X-rays. The study of light energy is known as optics.

The main reason life exists on Earth and not on other planets is because our atmosphere allows the right amounts of the different forms of light energy coming from the Sun to reach the surface. Plants rely on the light and heat from the Sun to make their own food and, of course, to provide food for animals.

We are now trying to capture the light energy as efficiently as plants do. The relatively recent invention of **solar cells** to turn light from the Sun directly into electricity is now used to power many devices, such as calculators, street lights and even cars.

Figure 2 Sunlight is essential for all life on Earth. Without it, it is doubtful whether life would exist.

CHALLENGE

3.3: Exploring sound energy
Go to page **186**.

Figure 3 Solar-powered speed signs are becoming common all across our country and help to save energy.

Heat energy

Heat energy is more scientifically known as **thermal energy**. Thermal energy can be generated by friction, such as by rubbing your hands together or by the rubbing of a car's tyres on the road. It is also commonly generated by burning chemicals or by electrical devices. We experience heat energy being transferred from a high temperature place to a lower temperature place as we heat up or cool down. For example, an ice block feels cool because it takes the thermal energy away from our hands.

Figure 4 The heat of a 'burn-out' creates great clouds of smoke.

Electrical energy

All substances are made up of positive and negative electric charges that, when separated, have **electrical energy**. This means that they are in a state of excitement and are trying to get back together again. If the positive and negative charges are locked together in one area, such as a wire, the separated charges can easily move back together. As they try to connect, the electrical energy they had when separated gets changed into light, heat or movement that we see in electrical lights, heaters or motors.

Sound energy

Have you been at a very loud concert and stood near the huge speakers? If so, you will remember that you not only heard the deep bass sound, but also felt it in your body. You can feel the same vibrations in the car if you put your hand on the dashboard when the sound system is on full volume. Sound is made when things vibrate. Every time you make a sound – whether it be playing a musical instrument or speaking or singing or even whispering – you are making vibrations. Vibrations are simply tiny movements back and forth. Vibrations can occur in gases, liquids and solid things such as speakers – even the desk in front of you. Energy is needed to make sound. For example, unless a drummer uses energy to hit the drums, the drum skin will not start to vibrate and will not make a sound. So, do you think **sound energy** is a type of kinetic energy?

electrical energy
energy associated with electric charge, either stationary (static) or moving (current)

thermal energy
the scientific term for heat energy

sound energy
a type of kinetic energy produced when things vibrate, causing waves of pressure in the air or some other medium

3.3 Check your learning

Remember and understand

1 **Identify** the scientific term for 'movement energy'.
2 **Describe** what is moving in electrical energy.
3 **Describe** what is moving when a guitar produces sound energy.
4 **Identify** another name for heat energy.
5 **Describe** how solar cells are used in the transfer of energy.

Apply and analyse

6 **Identify** the features of a car that would absorb the driver's kinetic energy in a collision.
7 **Compare** (the similarities and differences between) kinetic energy and potential energy.

Figure 5 Musical instruments use kinetic energy to produce sound.

3.4 Energy can be transformed

Interactive 3.4
Energy transformations

In this topic, you will learn that:

- energy that changes from one form to another is transformed.
- flow diagrams use arrows to show the direction that energy moves.
- electricity can be generated when turbines are turned by water, wind or coal generated steam.

transformed describes energy that has changed into a different form

When energy is changed from one type of energy to another, we say it has been **transformed**. For example, when the energy in a battery is transferred to the wires in a circuit, the energy is transformed from chemical potential energy into electrical energy (see Figure 2). Water at the top of a waterfall has gravitational potential energy. This is transformed into kinetic energy as the water moves down to the bottom of the waterfall. Before investigating energy transformations, there are a few things you need to know.

Figure 1 In light bulbs, electrical energy is transformed into both light energy and thermal energy.

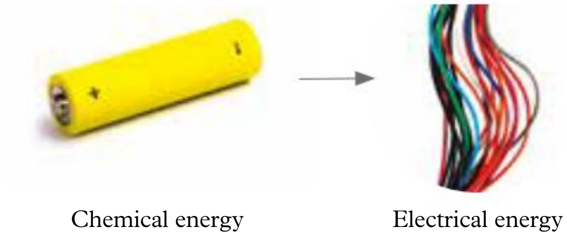


Figure 2 A flow diagram showing how a battery transforms chemical energy into electrical energy.

Figure 3 Chemical energy in the mobile device battery is transformed into the sound energy that we hear.

Flow diagrams

How do we represent an energy transformation scientifically? Flow diagrams that use an arrow to represent the transformation process help with this idea.

1. The arrow points in the direction of the transformation.
2. The starting energy input is written at the back of the arrow.
3. The useful energy output is written in front of the arrow.

Sometimes there is more than one energy output, so we try to concentrate on the main one. The extra energy outputs are known as by-products. Think of how you would write the energy transformation in a light bulb. What is the energy input? What is the main energy output? Is there a by-product (wasted energy)?

In some devices there are several energy transformations that make up an energy story, resulting in an energy chain. For example, the energy story in a mobile device would be described in the following way:

The chemical energy stored in the battery is transformed into electrical energy. The electrical energy flows through the wires to the headphones, where it is transformed into kinetic energy as the tiny speakers in the headphones vibrate. This is then transformed into sound energy, which our ears pick up.

As a flow diagram, this energy is shown in Figure 3.

Generating electricity

There are many ways to generate electricity. Many technologies use different methods to turn a turbine. Wind generators use the wind to turn the turbines. The kinetic energy of the wind is transferred to the kinetic energy of the turbines. The turbines then transform this energy into electrical energy (see Figure 4).

CHALLENGE
3.4: Energy converters
Go to page **186**.

Hydroelectric plants have large dams that store water. The large amount of water is usually part of the way up a hill. Therefore the water has gravitational potential energy. Pipes control the flow of water down through the turbine, transforming the gravitational potential energy into the kinetic energy of the turbines (see Figure 5).

Coal-based electricity generators burn coal to heat water. The resulting steam rises, forcing the turbines to turn and transform the kinetic energy into electrical energy (see Figure 6).

You use the electrical energy that comes from these generating plants for many different things: charging your mobile phone, cooking dinner, switching on a light. Energy may take many shapes or forms before you can use it.


Kinetic energy of air → Kinetic energy of wind generator → Kinetic energy of turbines → Electrical energy of wires

Figure 4 The transformation of kinetic energy


Gravitational potential energy of water → Kinetic energy of water → Kinetic energy of turbines → Electrical energy of wires

Figure 5 The transformation of gravitational potential energy

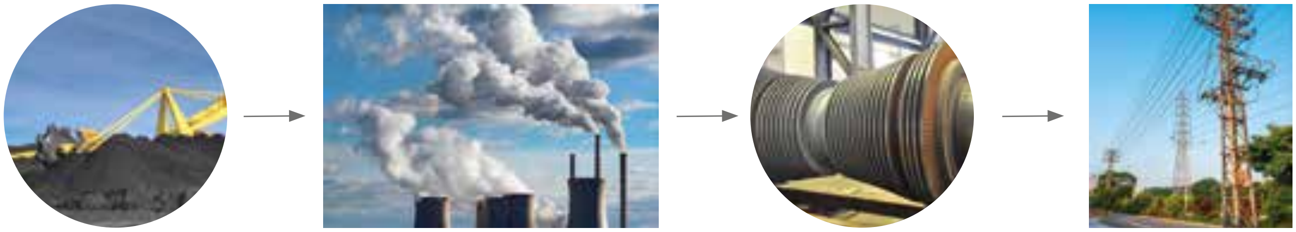

Chemical potential energy of coal → Kinetic energy of steam → Kinetic energy of turbines → Electrical energy of wires

Figure 6 The transformation of chemical potential energy

3.4 Check your learning

Remember and understand

1 For each of the electricity generators above, draw a flow diagram of the energy transformations.

2 **Identify** where the energy stored in coal comes from.

3 **Contrast** (the differences between) energy transformation and energy transfers.

4 **Identify** one way that energy can be transferred without being transformed.

Apply and analyse

5 Draw a flow diagram for the main energy transformations in a moving car.

6 Draw an energy chain that shows how we get our energy from eating an apple. (HINT: Start with the Sun!)

3.5

Energy cannot be created or destroyed

In this topic, you will learn that:

- the law of conservation of energy states that energy cannot be created or destroyed.
- when energy is transformed or transferred, waste energy is produced.
- efficient transformations or transfers produce less waste energy.

law of conservation of energy
a scientific rule that states that the total energy in a system is always constant and cannot be created or destroyed

energy efficiency
a measure of the amount of useful energy transformed in an energy transformation process; usually expressed as a percentage of the input energy (e.g. 90 per cent efficiency is very good)

Law of conservation of energy

If all the input energy could be added up and compared with all the output energy, it would always be the same. The total energy remains constant, but the type of energy may change – what goes in must come out!

This is considered the **law of conservation of energy**. No energy can be created or destroyed. The energy at the end must be equal to the energy present at the beginning. When you lift an object up in the air, you add gravitational potential energy. This energy did not just appear. The kinetic energy of your hand was conserved and transformed into the gravitational energy of the object. When the object is dropped, the energy is not destroyed. The gravitational energy is once again transformed into kinetic energy as it falls. When the object hits the ground it might bounce back, but it never reaches the starting height. Waste energy is lost, affecting the energy efficiency of the object.

Energy efficiency

If a device like a trampoline transforms most of its input energy into the most useful output energy, then it is considered to be a very energy-efficient device. The less 'wasted' energy, the more energy-efficient the device. **Energy efficiency** is a calculation of the percentage of useful energy transformed.

$$\text{Efficiency} = \frac{\text{Useful energy output}}{\text{Energy input}} \times 100$$

Take the trampoline example in Figure 1. The input energy was 500 units and the useful output energy was 400 units. This means that the trampoline is 400 ÷ 500 × 100 = 80% efficient, which is not too bad. Worked example 3.5 shows how to calculate energy efficiency.

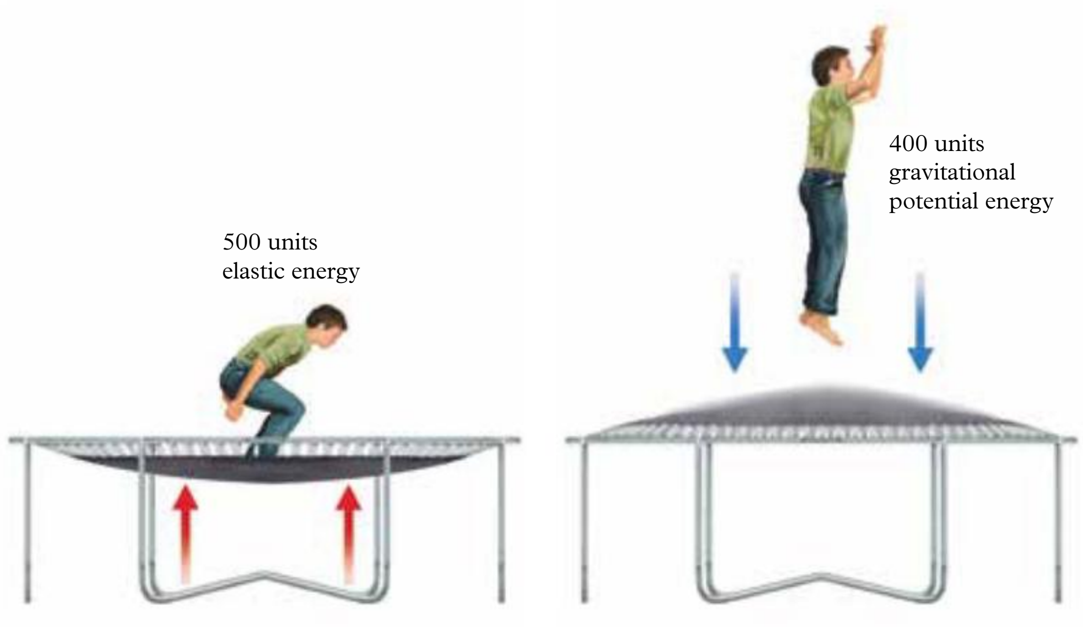


Figure 1 Five hundred units of energy are stored in the springs of the trampoline. At the highest point, the jumper has 400 units of gravitational potential energy. Where have the 100 'missing' units gone?

EXPERIMENT

3.5: What if you bounced a ball? Go to page **187**.

Worked example 3.5 Calculating energy efficiency

Todd held a tennis ball 1.5 m above the concrete before letting it fall. The ball hit the concrete before bouncing to 90 cm above the ground.

a Calculate the energy efficiency of the tennis ball.

b Calculate the waste energy as the tennis ball bounced.

Solution

a Input gravitational energy comes from the ball at 1.5 m (150 cm) above the ground.

Useful output gravitational energy is shown by the ball being 90 cm above the ground.

$$\text{Efficiency} = \frac{\text{Useful energy output}}{\text{Energy input}} \times 100$$

$$= \frac{90}{150} \times 100$$

$$= 60\%$$

The tennis ball has an energy efficiency of 60%.

b The ball is 60% efficient.

$$\text{Waste energy} = \text{Energy input} - \text{Useful output energy}$$

$$= 100\% - 60\%$$

$$= 40\%$$

Therefore 40% of the energy is transformed into waste energy.

Most energy transformations for everyday appliances aren't as efficient. Scientists are constantly trying to design the best appliances possible with the highest efficiency ratings. This would make them better for the environment and cost less to power. Do you and your family always buy the most efficient appliances? Are you familiar with the star ratings on appliances? More stars mean that the appliance is more energy efficient. Not only is it good to know that less energy is being wasted, but it also means that, on your electricity and gas bills, you are paying for energy that is being used rather than for energy that is being wasted.

Heat and sound waste energy

If no system is 100 per cent efficient, but the energy cannot be destroyed, then where does the energy go? In most cases, the energy is transformed into heat and sound energy. Think what happens when you drop a ball on the ground. The ball starts with gravitational potential energy, which is transformed into kinetic energy when you drop it. When the ball hits the ground it makes a noise. The larger the noise, the more sound energy is generated. If you bounce a ball many times in a row, you might be able to feel the ball start to warm up. Heat energy is generated. Both the heat and sound energy dissipate into the air. They are not lost or destroyed. We cannot reuse them. They are by-products of the main energy transformation.

Figure 3 When a rubber band is stretched, it contains elastic energy.

Figure 2 When you drop a basketball on the ground, gravitational potential energy is transformed into kinetic energy.

3.5 Check your learning

Remember and understand

1 **Describe** the law of conservation of energy.

2 The Sun provides heat and light energy to our planet every day. Some of this energy becomes waste energy. **Describe** where most of the useful energy goes.

Apply and analyse

3 **Explain** why a rubber band that has 10 units of elastic energy cannot produce 12 units of kinetic energy.

4 For the rubber band in question 3, **calculate** what its percentage efficiency would be if 7 units of kinetic energy were produced. **Describe** where the remaining 3 units of energy have gone.

5 A student claimed energy was lost when they bounced a ball. **Evaluate** whether the student is correct by:

- describing the law of conservation of energy
- describing how this law applies to the student's statement
- deciding if the statement is correct.

6 **Describe** the by-product of energy transformations for a car.

3.6 Energy efficiency can reduce energy consumption

In this topic, you will learn that:

- understanding how waste energy is formed allows it to be minimised.
- waste energy can be useful.
- insulation prevents the transfer of thermal (heat) energy.
- knowledge and understanding of energy transformations is not just limited to scientists. A variety of people use this knowledge in their everyday lives.

Figure 1 Appliances such as toasters use electrical energy to cook food.

Using electricity

A hair dryer has two basic components: a fan and a heating element. When plugged in and switched on, the fan motor spins and the heating element heats up. So, a hair dryer converts electrical energy into thermal (heat) energy and kinetic energy. The air blown by the fan is directed over the heating element, passing the heat energy to the air, which flows out of the hair dryer. Some hair dryers have different speed and heat settings that control the amount of electrical energy flowing to each part of the device.

Other heating devices, such as toasters, also use heating elements to convert electrical energy into thermal energy. Heating elements are made of certain types of wires that heat up without melting when electricity flows through them. The thermal energy is then passed to the air, which then passes the heat to the bread, toasting it.

Microwave ovens cleverly convert electrical energy into microwaves, which heat our food. Electric ovens are like oversized toasters and can have a fan in them, like in a hair dryer. Gas ovens and stoves use the chemical energy of the gas to produce heat by burning the gas. The more efficient this transformation is, the less energy is wasted.

Figure 2 Insulation prevents heat energy being transferred between the inside and the outside of the house.

Controlling thermal energy

When energy is transformed, thermal energy is often produced as a waste product. For thousands of years this knowledge has been used by Aboriginal and Torres Strait Islander peoples to turn thermal waste energy into useful energy in the generation of fire. The fire drill or firesticks method involves pushing the blunt end of a long thin drill stick into the flat surface of wood. For this method, soft wood is best (for example, wood from a grass tree or the stalk of a Xanthorrhoea flower). As the drill stick is rubbed between the hands, the kinetic energy causes it to twist into the flat wood. The friction between the two pieces of wood produces thermal waste energy in the flat wood, eventually causing it to catch on fire. From the fire, embers are created, which are moved to dry grass and blown to ignite a flame.

Heating and cooling your house

No doubt your house has some sort of heating or cooling system, depending on where you live. You probably use electricity or gas to do this. In a hot environment, energy is needed to remove the heat from inside your home, allowing it to cool down. The warm air inside the house is moved over cool pipes in the air conditioner. The thermal energy of the house air is passed to the refrigerant inside the pipes and is then carried outside the house. If the house is well designed, then the thermal energy remains outside and the house stays cool.

Architects design homes to help control the flow of thermal energy. They can add a variety of features that help to limit the amount of heating or cooling your house needs.

Insulation

Lining the inside of the walls, floors and roof of your house can make sure that the heat is not transferred between the outside air and the inside of the house. Insulation is a material that prevents the transfer of energy. An insulated house will keep the heat inside on a cold day, and outside on a hot day.

CHALLENGE

3.6: Design an energy-efficient house
Go to page **188**.

Window awnings

One of the main places heat is transferred is through a window. On a hot day, the light and heat from the Sun easily penetrate a window.

This transfers the heat into the house. A shade or awning on a window can limit this. Limiting the number of windows facing the Sun can also help to prevent the heat being transferred into the house.

Veranda

A veranda works much like an awning, but it also prevents the heat and light from the Sun from shining on the walls. This prevents the heat from being transferred to the walls, and then to the air inside.

Figure 3 A veranda prevents heat being transferred from the Sun to the walls of the house.

3.6 Check your learning

Remember and understand

1 Draw an energy flow diagram for the fire drill firestick method used by Aboriginal and Torres Strait Islander peoples.

2 Draw flow diagrams for the energy transformation process that happens in your house for:

  a heating during winter

  b cooling during summer.

3 A refrigerator cools the food inside it.

  a **Describe** how the refrigerator keeps things cool.

  b **Describe** all the energy transformations that may occur in a refrigerator.

4 **Describe** how architects use their knowledge of energy efficiency to minimise the energy used in a house.

5 **Describe** how window awnings and verandas keep a house cool in summer.

Apply and analyse

6 The temperature inside and outside a house was measured over 24 hours and displayed in Figure 4. From the graph, determine whether the house was insulated. **Justify** your answer (by comparing how the temperature inside and outside the house will change over a day, describing how insulation affects the temperature inside the house and using numbers from the graph as evidence to support your decision).

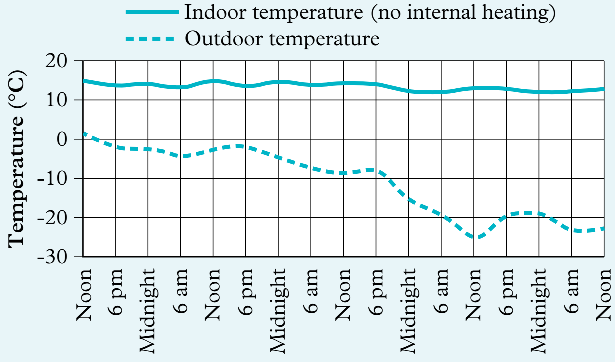


Figure 4 A graph of the temperature inside and outside a house

7 Study Figure 6, which shows how much energy is used by different household appliances.

  a **Identify** which appliance uses the most energy.

  b The clothes dryer uses more energy than the electric blanket. Use energy transformations to **explain** why.

  c Many people switch their appliances off at the wall rather than use the standby function (where the television is still on but the screen is dark). **Compare** the possible costs of switching the appliance off or using standby.

Figure 5 An energy-hungry appliance

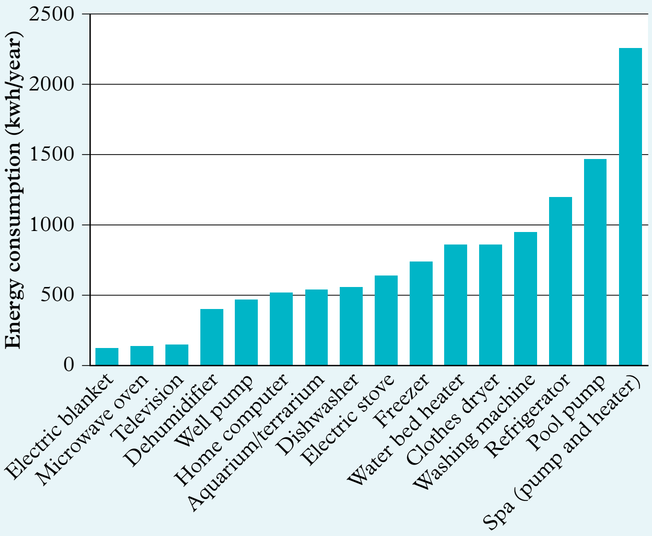


Figure 6 A graph of the energy consumption of different household appliances

//SCIENCE AS A HUMAN ENDEAVOUR//

3.7 Engineers use their understanding of energy to solve problems

The word 'engineer' comes from the Latin words *ingeniator* or *ingenium*, which literally mean 'ingenious one'. Engineers use science and mathematics to provide solutions, shape future developments and generate ideas that make life easier. All engineers are problem solvers, but some know how to solve specific problems better than others. People who study to become engineers often choose an area of interest and concentrate their skills in that field.

motion
when an object changes its position over time

Chemical engineers

Chemical engineers combine existing materials and develop new materials. These materials can then help other engineers to build structures. Chemical engineers also consider where the materials come from, whether they are being used sustainably, and how much energy is required to process and transport them.

Mechanical engineers

Mechanical engineers deal with forces and **motion** – designing and improving things that have moving parts or have physical forces pushing or pulling them. This includes large structures, such as water slides, where the gravitational potential energy at the top is used to provide kinetic energy (speed) at the slide's base. Reducing the friction of the slide makes it more efficient, and therefore more of the potential energy will be transformed into kinetic energy (speed) at the base. Mechanical engineers have produced some of the most important and useful inventions in history including the zip and the yo-yo!

Figure 1 Yo-yos are fun toys that use mechanics to work.

Figure 2 Water slides transform the gravitational potential energy of the water into kinetic energy. Reducing the friction of the slide makes it more efficient.

CHALLENGE

3.7A: Leakywater Council swimming pool and waterslide
Go to page **189**.

EXPERIMENT

3.7B: Investigating structures and materials using icy pole sticks
Go to page **191**.

Electrical engineers

Electrical engineers design and organise electrical equipment. This equipment may be used for satellites, computers and medical equipment. They are also involved in developing electricity supplies, including the development of alternative energy sources.

Civil engineers

Civil engineers research, plan and design structures. They know about the physical properties of materials. They are interested in how different materials perform under different conditions. For example, tall buildings need to remain secure in high winds.

Evaluating a proposal

When engineers design and evaluate different options for a project there are three main points to consider.

1 Will the option do the job it is expected to do?
2 How well does the option do that job? Is there a better way?
3 Is the option cost-effective?

Other points also need to be considered, like how long each option will take to build, cost, availability of materials and impact on the environment.

The simplest way to compare different options for a project is to use a **cost–benefit analysis**. In a cost–benefit analysis, an engineer makes a list of all the potential benefits of each option, such as for the community in terms of profits. These are then compared to the costs of each option, including both the financial costs and the risks of environmental or other damage. When all the options have been analysed in this way, the engineer can more easily compare the options and decide which one is best. The best option would have the most benefits and the least costs.

cost–benefit analysis
a list of costs compared with benefits, usually used to analyse a proposed engineering project

Figure 3 Mechanical engineers work with forces and motion.

3.7 Develop your abilities

Communicating the science: Budj Bim eel traps

In south-west Victoria the Gunditjmara people engineered a complex series of channels, weirs and dams to trap eels (kooyang) so that they could be farmed and collected as a reliable food source. Some of these channels are hundreds of metres long. The construction of these channels in the old Budj Bim lava flows required a good understanding of the kinetic energy of water and how the energy can be transformed to potential energy when it is stored behind a stone dam.

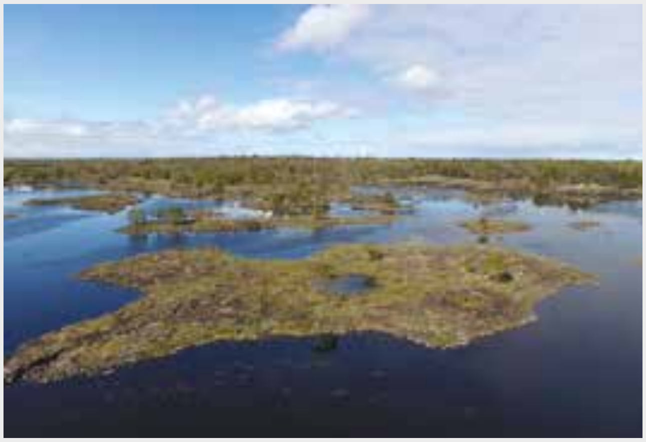


Figure 4 Part of the Budj Bim National Heritage Landscape, Lake Condah once featured an extensive aquaculture system.

Engineering projects such as this one are designed and evaluated using many different **criteria**, including how it will impact the people, animals and plants in the area.

There are many examples of engineering assessments. Write an engineering report on the Budj Bim eel traps by answering the questions below.

- **Social impact assessment – Explain** whether the project will have a good or bad impact on people's lives.
- **Risk assessment – Describe** what might happen if the project fails.
- **Environmental impact – Describe** the effects the eel traps will have on the environment.
- **Contamination assessment – Identify** whether any chemicals used in the project will contaminate living things.
- **Strength and facility life assessment – Describe** the loads the structure will need to withstand. **Describe** how long the structures will survive.
- **Geotechnical hazard assessment – Describe** any problems that might be experienced with digging the soil.

//SCIENCE AS
A HUMAN ENDEAVOUR//

3.8

Solar cells transform the Sun’s light energy into electrical energy

A solar cell is any device that transforms the Sun’s light energy into electrical energy. The number of households using light energy to heat water or power heating and cooling devices is growing rapidly every year.

Video 3.8A
Ask a scientist – Dr Niraj Lal (Physicist)

Video 3.8B
Solar panel roads in France

Using solar energy in Australia

Australia is often known as the sunburnt country. This is a reference to the large number of hours each day that the Sun shines. Australia is a big country and the number of hours varies greatly depending on the location and the time of year. Solar energy is often measured in the number of peak sunlight hours every day (see Figure 1). This is then averaged out over the whole year. For example, in the Hunter Valley in New South Wales, the number of peak hours can be as low as 4.0 hours/day in winter and as high as 6.5 hours/day in summer. Over a year this averages out to 5.6 hours/day. In Tasmania the average number of peak hours is 3 hours/day. In Queensland, the Northern Territory and Western Australia, the average number of peak hours each day is 6.

Converting light energy into chemical potential energy

Using light energy to power a house has its problems. The most common time people use electrical energy is not when light energy is available. This means the light energy often

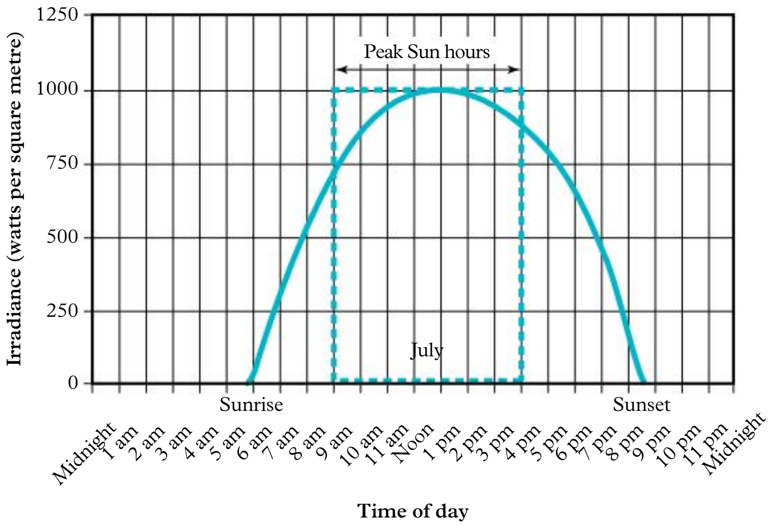


Figure 1 A graph showing the peak Sun hours over a day

CHALLENGE

3.8: The Sun's energy
Go to page **192**.

Figure 2 The Tesla Powerwall is a rechargeable battery system that is used to store solar-generated electricity for use in homes and businesses.

needs to be stored so that it can be used at night. The light energy is transformed into potential chemical energy in a battery so that it can be used to heat water, provide light or supply energy for cooking.

photovoltaic cell (PVC)
an electrical device that converts light energy into electrical energy; see solar cell

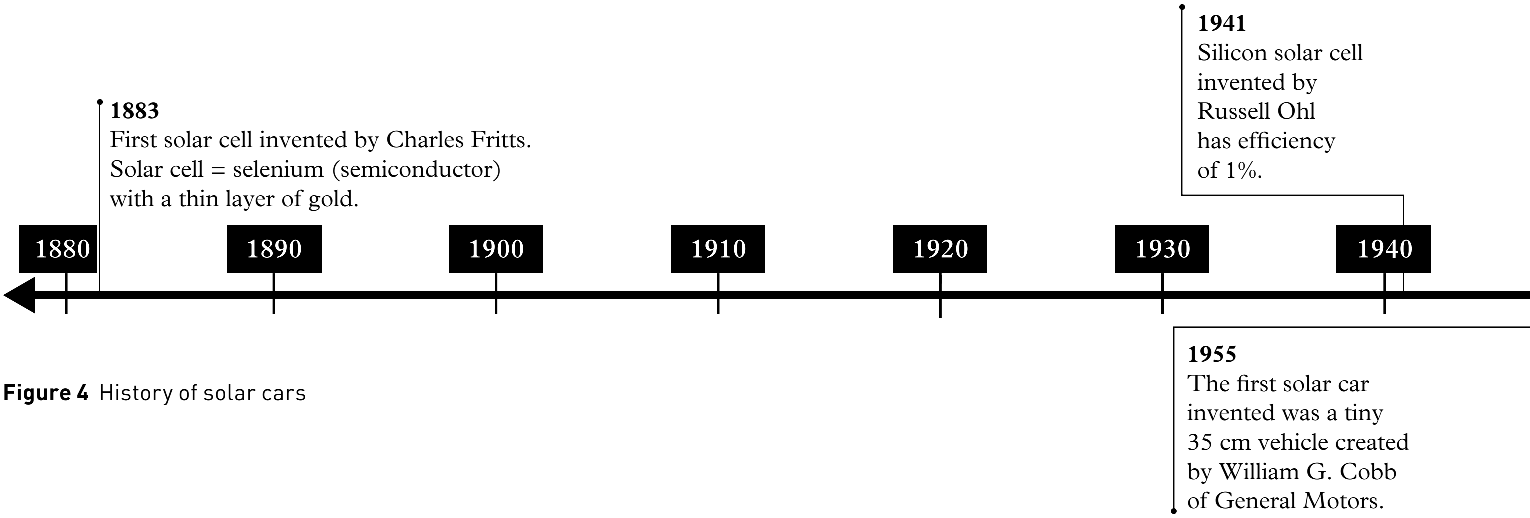
Capturing the light energy

Solar panels are a collection of solar cells called **photovoltaic cells (PV cells)**. When light shines on the surface of these PV cells, the light energy is transformed into electrical energy. The most efficient PV cells currently convert 30 per cent of the energy they receive from the Sun.

Solar cars

Most current solar-powered vehicles only carry one person. They are lightweight (approximately 600 kg) so that they are more energy efficient. Solar energy can be used to charge the batteries used in the electric cars found on our roads. The number and types of electrical vehicles available are increasing every year.

Figure 3 A three-wheeled solar car with a solar panel on the roof



1883
First solar cell invented by Charles Fritts.
Solar cell = selenium (semiconductor)
with a thin layer of gold.

1941
Silicon solar cell
invented by
Russell Ohl
has efficiency
of 1%.

1955
The first solar car
invented was a tiny
35 cm vehicle created
by William G. Cobb
of General Motors.

Figure 4 History of solar cars

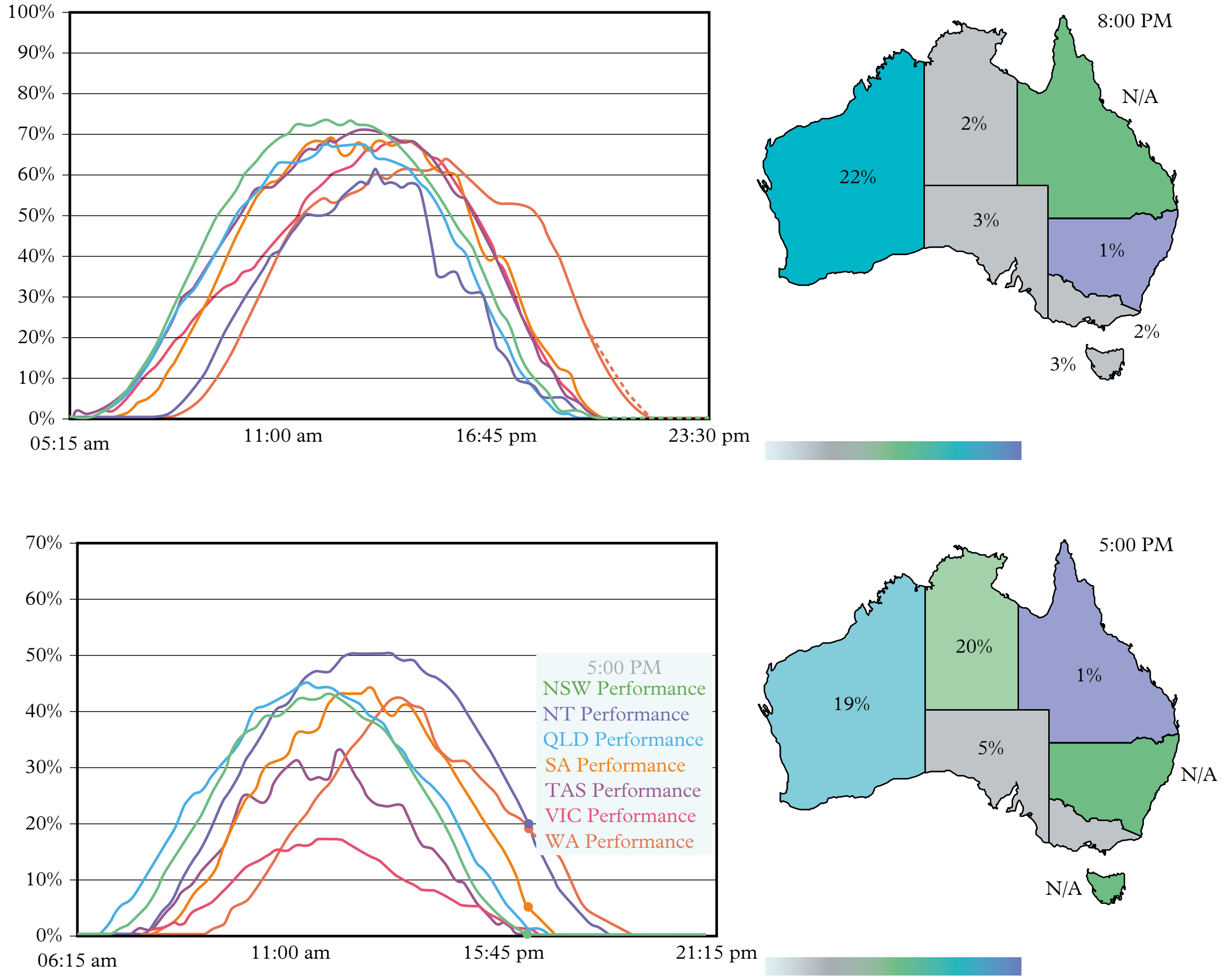
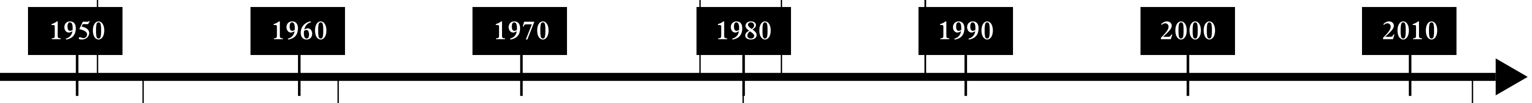


Figure 5 Estimated photovoltaic output as a percentage of its maximum capacity in each state at different times of the year



1954
Gerald Pearson, Calvin Fuller and Daryl Chapin improved the efficiency to 6%. Silicon strips were used to create the first solar panels.

1962
International Rectifier Company designed the first solar car that could be driven. They converted a vintage 1912 Baker electric car to run on approximately 10 640 PVCs.

1977
Alabama University professor Ed Passerini constructed his own solar-powered car called 'Bluebird'.

Figure 6 A 1970s electric CitiCar

1980
Englishman Alain Freeman road-registered a 3-wheeler solar car with a solar panel on the roof.

1980
Arye Braunstein and colleagues at Tel Aviv University (Israel) designed a solar car with a solar panel on the roof and hood of the car. The car was recorded reaching 65 km/h with a top speed of 80 km/h.

1982
Larry Perkins and Hans Tholstrup constructed and drove the 'Quiet Achiever', a home-made vehicle, from the east coast of Australia to the west coast. Their feat is recognised in the World Solar Challenge, a solar car race that allows solar car designers to compete in a race across Australia every two years.

1987
GM Sunraycer completed a 3010 km trip in California with an average speed of 67 km/h.

2014
A solar-powered family car (with four seats) called 'Stella' was driven 613 km from Los Angeles to San Francisco.

3.8 Develop your abilities

Analysing graphs

The amount of (photovoltaic) sunshine available across Australia changes according to the time of the year (see Figure 5). Photovoltaic data is collected by a number of Australian research groups to track the effectiveness of energy transformation from light energy to electrical energy.

Analyse the graphs by answering the questions below.

1 **Identify** the variable on the horizontal axis.
2 **Identify** the variable on the vertical axis.
3 **Identify** Victoria's maximum percentage of photovoltaic capacity from the graphs.
4 The data was collected at different times of the year. **Evaluate** which graph represents winter and which graph represents summer by answering the following:
    - **Identify** which graph has the highest value.
    - **Explain** how the different seasons affect the level of sunshine available in Victoria.
    - **Decide** which season produces the highest percentage of photovoltaic capacity.
5 **Evaluate** which state is capable of transforming the most light energy into electrical energy through the use of photovoltaic cells by answering the following:
    - **Identify** which state has high percentages of photovoltaic capacity in both seasons.
    - **Explain** why transforming light energy across the whole year is more important than transforming the most light energy in just one season.
    - **Decide** which state is capable of transforming the most light energy into electrical energy.

REVIEW 3

Multiple choice questions

1 **Identify** the correct definition for 'energy'.

- **A** the ability to heat or light things
- **B** the ability to do work
- **C** the ability to create movement
- **D** the flow of electricity through a circuit

2 **Identify** which of the following is true about energy.

- **A** Energy cannot be created or destroyed.
- **B** Energy is destroyed once it has been used.
- **C** Energy is created constantly.
- **D** Energy is precious because it is difficult to find.

3 **Identify** how insulation can help to make a house more energy efficient in summer.

- **A** It captures light energy to power the house.
- **B** It stops heat getting in through the windows.
- **C** It deflects light energy away from the house.
- **D** It helps to keep heat out of the house during the day.

Short answer questions

Remember and understand

4 Match these words and phrases with their correct meanings.

Word/Phrase	Meaning
Kinetic energy	The energy stored in a compressed spring
Nuclear energy	Another name for stored energy
Potential energy	The energy of an object when lifted up
Elastic energy	Used widely throughout the world to generate electricity from atoms
Gravitational energy	Possessed by all moving objects

5 **Identify** which of the following is true or false. For false statements, rewrite them to make them correct.

- **a** Springs only hold stored energy when they are stretched.
- **b** When an object is thrown up in the air, it gains gravitational potential energy.
- **c** Sound energy is a type of potential energy.
- **d** Petrol contains nuclear energy.

6 **Identify** the main form of energy in each of the following situations:

- **a** water flowing slowly over a waterfall
- **b** a rollercoaster at the lowest point of the ride
- **c** the Sun coming in through a window on a sunny day
- **d** a boy riding his skateboard
- **e** a stretched rubber band.

7 **Identify** a device that transforms:

- **a** electrical energy into light energy
- **b** elastic energy into kinetic energy
- **c** electrical energy into sound energy
- **d** gravitational energy into electrical energy
- **e** kinetic energy into electrical energy.

8 **Explain** why a chemical engineer might be employed to design a new clothing range.

9 **Describe** two different ways electrical energy can be generated.

10 **Contrast** (the differences between) the terms 'transform' and 'transfer'.

11 **Compare** (the similarities and differences between) potential energy and kinetic energy.

Apply and analyse

12 Use numbers in an example of your own to **explain** the law of conservation of energy.

13 Use numbers in an example of your own to **explain** energy efficiency.

14 **Calculate** the percentage efficiency of a device if it transforms:

- **a** 20 units of input energy into 12 units of useful output energy
- **b** 600 units of input energy into 500 units of useful output energy.

In (a) and (b) above, describe where the other energy (i.e. 8 units in (a) and 100 units in (b)) went.

15 The main job of a car travelling on the road is to produce kinetic energy in its wheels. **Identify** the other parts of a car that may demonstrate kinetic energy.

16 Think of your day today. **Identify** the different energy forms you have come across, possessed, used or witnessed. List them in order of use during the day. **Describe** which energy form was the most common and why.

17 Visit a local playground and examine the play equipment. Take a photo or draw a picture of a piece of equipment and work out what types of energy are demonstrated as a child plays on the equipment.

Evaluate

18 **Identify** the places and structures in your school that you think an engineer was involved with. **Justify** your decisions (by identifying the role an engineer would have played in the design of the structure).

19 Energy types rarely exist alone. They are always on the move, making things happen. Think about some of the things energy can do. For at least two of these, **identify** the type or types of energy involved. If more than one type of energy is involved, link the different types with arrows. Try to include as many different scenarios as you can.

Social and ethical thinking

20 The transformation of chemical energy found in coal and gas into electrical energy has resulted in an increase in the level of carbon dioxide in the air. Despite the advantages of solar (photovoltaic) panels in producing electricity, their production can produce dangerous chemicals such as sodium hydroxide and hydrofluoric acid. **Evaluate** the effectiveness of using solar panels.

- **a** **Identify** the advantages and disadvantages of photovoltaic cells.
- **b** **Identify** the advantages and disadvantages of using an alternative source of energy (i.e. coal or gas).
- **c** **Compare** (the similarities and differences between) the two methods of producing electricity.
- **d** **Identify** the different groups of people who will be affected by these two methods.
- **e** **Decide** which method would be most beneficial to one group.

Critical and creative thinking

21 While clean energy projects like wind and solar farms are important in moving Australia towards a zero-carbon, renewable future, many of these projects are subject to Aboriginal rights and interests, though most Aboriginal and Torres Strait Islander peoples have little to no legal input during the planning stages for many of them. **Evaluate** the importance of consulting the traditional owners of the land you are working on or changing.

22 Energy comes in many different forms. **Create** a poster that illustrates each type of energy using visual examples.

23 The massive earthquake and tsunami in Japan in March 2011 caused extensive damage to the Fukushima nuclear power plant, north of Tokyo, and created an emergency situation. **Investigate** this disaster and present a 2-minute news report to the class that highlights the issues surrounding the use of nuclear energy.

Research

24 Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

» Compact fluorescent lights

Explain how compact fluorescent lights (CFLs) work. Explain how they differ from incandescent light globes. Explain why CFLs are initially more expensive to buy, but then more economical over time. Identify the benefit of using CFLs.

» Energy-efficient housing

In previous societies, energy efficiency was important because people had limited access to the types of energy supply and their applications compared to today. Research how civilisations in tropical areas designed their homes to keep them cool and damp free. Describe three types of energy-efficient practices that humans have used through the ages.

» New and specialised engineering fields

Select one of the newer fields of engineering like aerospace, biomedical or nuclear engineering. Describe what an engineer in that field does. Explain what they need to know. Identify who they work with. Describe where they work. Describe the materials they work with. Name a significant project the engineer has worked on.

» Plastic bank notes

Investigate the history of how Australia used chemical engineering to develop plastic bank notes. Identify the people who did this work. Describe the problem they were trying to solve. Describe the difficulties they encountered. Describe the features of our plastic bank notes.

Reflect

The table below outlines a list of things you should be able to do by the end of Chapter 3 ‘Energy’. Once you’ve completed the chapter, use the table to reflect on your ability to complete each task.

	I can do this.	I cannot do this yet.
Provide examples of types of energy and explain how energy cannot be created or destroyed, but can be passed between objects. Draw and interpret energy transfer diagrams.	☐	☐ Go back to Topic 3.1 ‘Energy can be transferred’ Page 42
Define potential energy, elastic potential energy, gravitational potential energy, chemical potential energy and nuclear energy. Relate changes in shape and position above the surface of the Earth and chemical bonds to potential energy transfers.	☐	☐ Go back to Topic 3.2 ‘Potential energy is stored energy’ Page 46
Define kinetic energy, electrical energy, thermal energy and sound energy. Provide examples of objects that use or have kinetic, electrical, thermal and sound energy.	☐	☐ Go back to Topic 3.3 ‘Moving objects have kinetic energy’ Page 48
Define and provide examples of energy transformation. Draw energy transformation diagrams.	☐	☐ Go back to Topic 3.4 ‘Energy can be transformed’ Page 50
Explain the law of conservation of energy. Relate the efficiency of an energy transformation with the amount of waste energy. Use the efficiency formula to calculate unknown values.	☐	☐ Go back to Topic 3.5 ‘Energy cannot be created or destroyed’ Page 52
Describe the importance of energy efficiency. Provide examples of features in building that improve energy efficiency.	☐	☐ Go back to Topic 3.6 ‘Energy efficiency can reduce energy consumption’ Page 54
Define cost–benefit analysis and criteria. Describe the roles of chemical, mechanical, electrical and civil engineers and explain the key steps involved in evaluating an engineering proposal.	☐	☐ Go back to Topic 3.7 ‘Science as a human endeavour: Engineers use their understanding of energy to solve problems’ Page 56
Describe the energy transfers involved in a solar panel. Provide examples of solar power use in Australia.	☐	☐ Go back to Topic 3.8 ‘Science as a human endeavour: Solar cells transform the Sun’s light energy into electrical energy’ Page 58

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Launch a quiz for your students on key concepts in this chapter.

CHAPTER 4

SOUND AND LIGHT

Why do we see lightning before we hear thunder?

What if?

String phones

What you need:

2 foam cups, 3 m of string, scissors

What to do:

1 Place a small hole in the bottom of each cup.

2 Poke each end of the string through the bottom of a cup and tie it off. The two cups should now be connected.

3 Pull the string taut between two people.

4 One person should speak quietly into the cup at one end while the second person listens in the other cup.

What if?

- What if the string was shorter? (Would the sound be louder or softer?)
- What if the string was longer?
- What if you used different types of string between the two cups?

4.1 Vibrating particles pass on sound

In this topic, you will learn that:

- sound is caused by the vibration of particles moving in a longitudinal wave.
- one wavelength is the distance between one compression of air particles and the next.
- the distance the air particle moves is called the amplitude.
- the number of waves passing a point each second is the frequency of the wave.

Video 4.1
Vibrating particles pass on sound

Modelling sound waves

We know that sound energy travels because we can often hear it a long way from its source.

Consider the example of a drum being played. The drum skin vibrates (moves up and down) when it is hit. The kinetic energy of the vibrations is transferred to the surrounding air particles, pushing them closer together in one place and forcing them further apart in another. In this way, the air around the drum is made to vibrate too. This causes the particles further away to vibrate, and so on, until the air close to your ears eventually vibrates and causes your eardrum to vibrate too. And that's when you hear the sound.

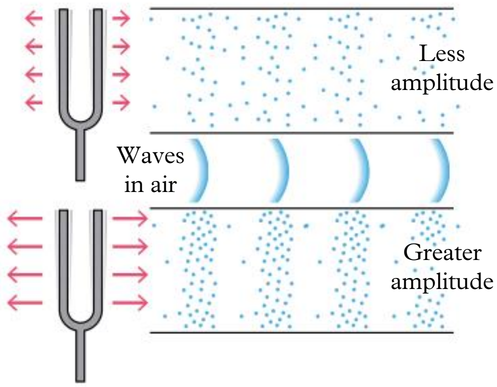


Figure 1 Red arrows indicate how far a particle in a sound wave moves.

The region with the particles forced close together is called a **compression**, and the less dense region where the air particles are further apart is called a **rarefaction**. Sound waves travel as a **longitudinal wave** because the air particles move back and forth parallel to the wave as the vibration passes through the air. The distance a particle of air moves is called the **amplitude** of the wave. Sound waves with a large amplitude mean the air particles move with greater kinetic energy. This makes the sound feel louder to our ears. An example of this is when musicians use amplifiers to increase the loudness of their music. Amplifiers increase the distance air particles move during compression and rarefaction.

A sound wave moves out in all directions from the place where the vibration began (see Figure 2).

compression
part of a sound wave where air particles are forced close together

rarefaction
a reduction in density; refers to part of a sound wave where air particles are forced apart

longitudinal wave
a type of (sound) wave where the particles move in the direction of travel of the wave

amplitude
the distance a particle in a wave moves, from its position of rest

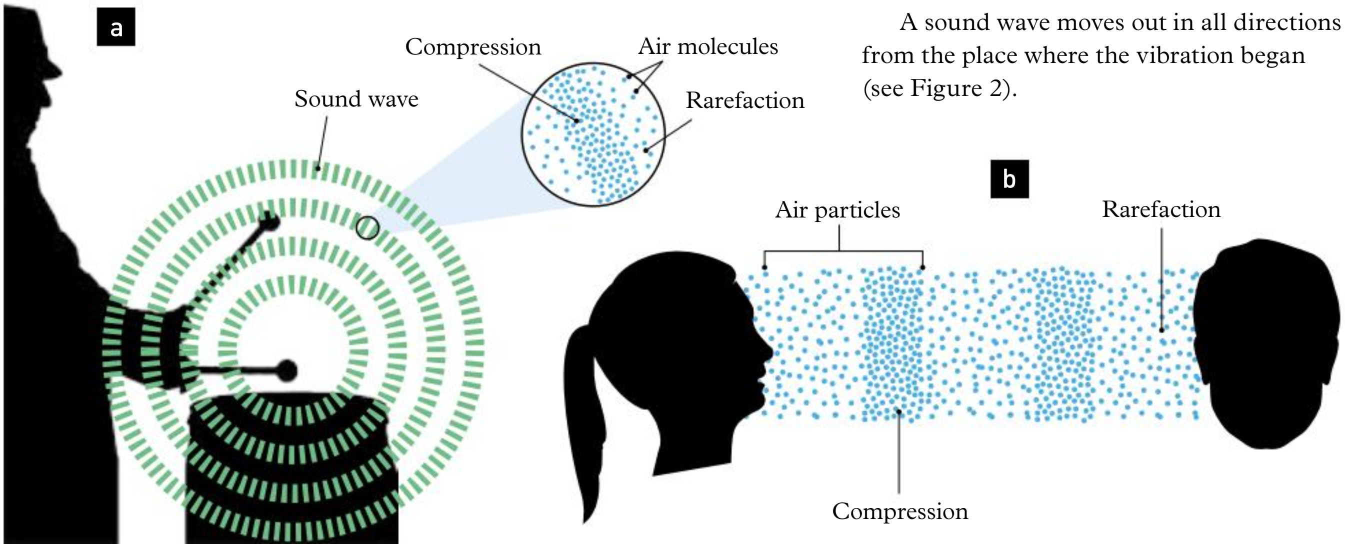


Figure 2 a When a drummer hits a drum skin, **b** a sound wave is produced.

CHALLENGE

4.1: Modelling sound waves
Go to page **192**.

Describing sound

You can sing high. You can sing low. You can talk in a funny voice if you want to because you can alter the number of vibrations coming from your vocal cords every second.

Compression waves can be close together or far apart. The distance between the start of one compression wave and the start of the next is called the **wavelength**. Short wavelengths mean more vibrations hit your eardrum each second.

When the waves travel close together, they are considered more frequent. The number of waves that pass a point each second is called the **frequency** of the wave. This is measured in the unit **hertz** (symbol Hz). We hear different frequencies as different pitches. For example, a soprano singer sings the high notes in an opera. These notes are high pitched. The sound waves for these notes have very short wavelengths and therefore high frequency. A deep bass singer is able to sing very low-pitched notes. These notes have long wavelengths and few of them can pass a point each second. Therefore, they have a low frequency.

As the waves move further away from their source, they lose energy and eventually fade out. As neighbours will confirm, the closer you live to a drummer, the louder they seem!

frequency
the number of waves that pass a point every second; measured in hertz

hertz
the unit used to measure frequency

wavelength
the distance between two crests or troughs of a wave

Figure 3 Middle C (shown in red) played on a piano has a wavelength of 1.33 m and creates vibrations at a frequency of 256 vibrations every second, or 256 Hz.

4.1 Check your learning

Remember and understand

1 **Describe** how the particles in air are arranged in a:
  a compression
  b rarefaction.

2 Work with a partner. **Explain** to your partner how the sound waves created by hitting a cymbal reach your ears. Use the following terms: compression, rarefaction, sound wave, spread out, air particles and ear. Write down your description.

3 Of the two springs shown in Figure 4, **identify** which demonstrates a:
  a lower frequency
  b shorter wavelength.

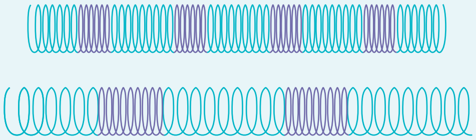


Figure 4 Springs

Apply and analyse

4 Imagine you have three tuning forks of frequencies 250, 500 and 1000 Hz. **Identify** the frequency that would have the:
  a lowest pitch
  b highest pitch.

5 **Explain** how the air moves when an opera singer sings a note.

6 **Contrast** the frequency and the pitch of sound.

7 **Investigate** the speed of sound in air.

4.2 Sound can travel at different speeds

In this topic, you will learn that:

- sound travels at 340 m/s at sea level at 20°C.
- the speed of sound varies according to the temperature and material through which it travels.
- particles have more kinetic energy at higher temperatures, so they can compress more easily.
- the more closely packed the particles, the faster the sound wave travels.

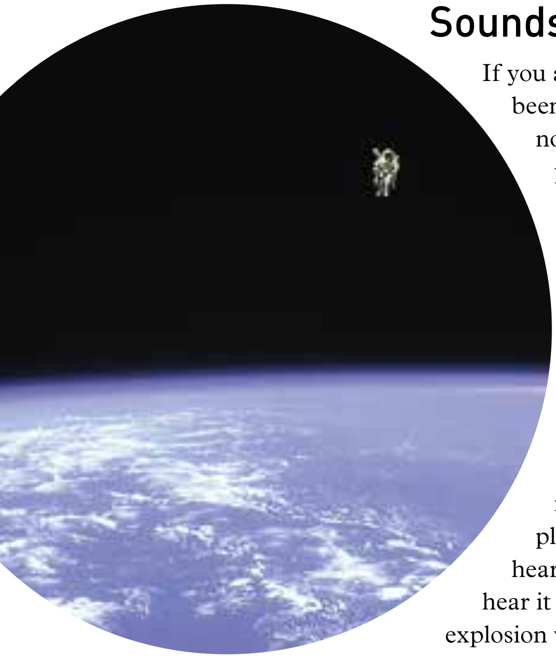


Figure 1 In outer space, there are so few particles of gas, and they are so far apart, that they cannot be compressed. As a result, outer space is silent.

Sounds of silence

If you are a drummer, you have probably been told more than once to 'keep the noise down!' But is there somewhere you could play your drum kit as hard and as loud as possible with absolutely no sound being heard? The answer is 'yes', but it is not a place you can get to easily.

A famous sci-fi movie was advertised with the tagline 'In space, no one can hear you scream'. The moviemakers were right. In outer space, you could play your drum kit without anyone hearing a sound – but you wouldn't hear it either. You could even see an explosion without hearing a thing. This is because sound needs something to travel through; it needs a substance (or medium) that contains particles that can be compressed to create the sound waves. The medium could be a solid, a liquid or a gas. In space, the particles are too far apart to push against each other.

Speed of sound

The speed of sound is affected by the closeness of the particles in a material, and how far they can move. For example, the particles in water are much closer together than in air. This means the water particles can move and compress more easily than air particles. Sound such as the song of a whale will travel more easily through water than air. The particles in a solid are packed even closer together. Therefore, sound will travel even faster in most solids (see Table 1).

The speed of sound also depends on the temperature of the material it is travelling through. Particles at higher temperatures have more kinetic energy. Since the particles are already vibrating fast, they can move more easily in a compression wave.

Table 1 Speed of sound in different materials and at different temperatures

Material	Speed (m/s)
Air at 0°C	331
Air at 20°C	343
Water at 20°C	1482
Lead	1960
Glass	5640
Steel	5960

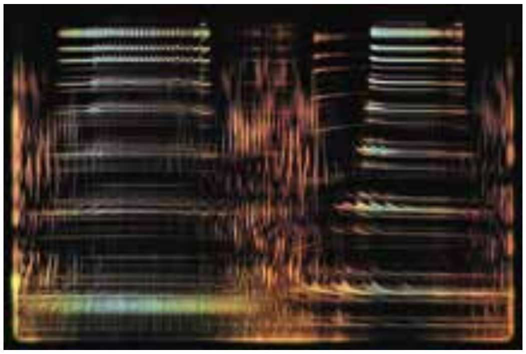


Figure 2 Sound travels five times faster in water than in air. Blue whales sing to each other in a series of moans, and pulses (shown) that can travel thousands of kilometres underwater.

Sonar

In all wars since the First World War, reflected waves have been used to detect enemy submarines under water. In a similar way to

CHALLENGE

4.2A: The speed of sound
Go to page **193**.

CHALLENGE

4.2B: Racing dominoes
Go to page **193**.

radar (radio waves), sonar sends out sound waves and records how long the sound takes to reflect or echo back after striking an object. The longer the sound takes to return, the further away the object. An exact location can be calculated by knowing how fast sound travels in water. This information, along with the time taken for the sound to return, allows the exact location of a submarine to be determined.

Sonar is widely used today and can help to map the ocean floor, check the depth of water and locate schools of fish.

Figure 3 Sonar is used to locate schools of fish in the ocean.

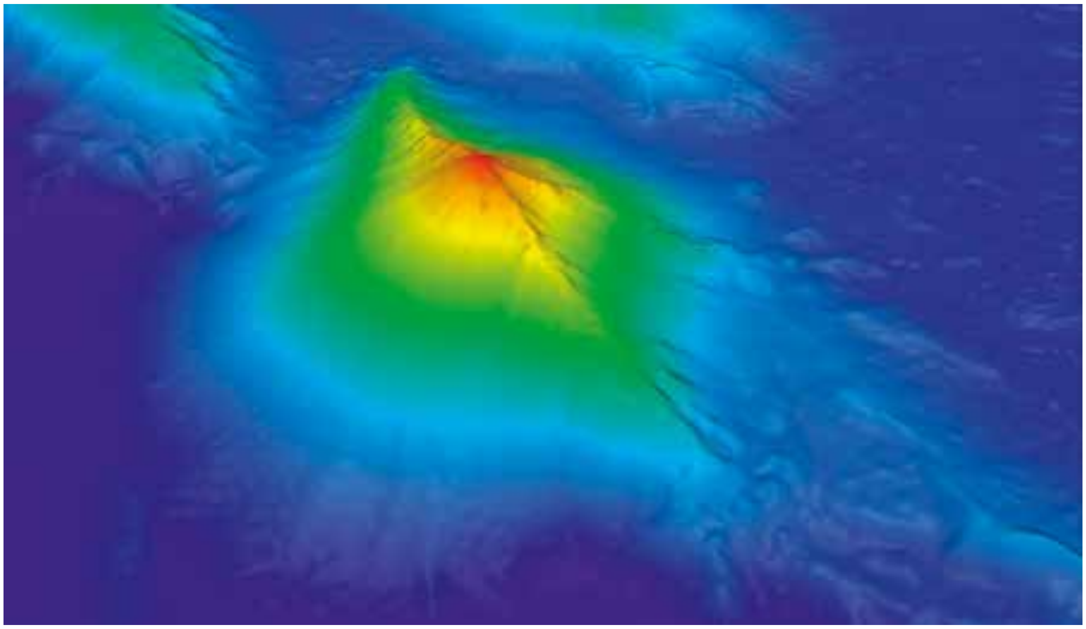


Figure 4 Sonar is used to map volcanoes on the ocean floor.

4.2 Check your learning

Remember and understand

1 **Identify** which of the following materials will allow sound to travel the fastest:
  - **a** water
  - **b** lead
  - **c** air
  - **d** glass.

2 **Describe** how sound moves through a liquid.

Apply and analyse

3 **Compare** (the similarities and differences between) sound moving through gases and solids.

4 Echoes occur when sound bounces off smooth surfaces. **Identify** which of the following is most likely to produce a loud echo. **Justify** your answer (by describing how sound moves in each case and deciding which will produce the loudest echo).
  - **a** talking in a furnished, carpeted room
  - **b** singing in a tiled shower
  - **c** yelling across an open field

5 **Explain** why we would not hear the noise of an explosion on Earth if a nearby star were to explode.

6 Many movies show people tapping SOS on water pipes to get help. **Explain** why tapping on water pipes is a quicker way of passing on a message than yelling.

4.3 Our ears hear sound

In this topic, you will learn that:

- sound is funnelled down the ear canal to the ear drum.
- the vibrations move through the ossicle bones in the middle ear to the inner ear.
- the fluid in the inner cochlea moves hairs attached to the auditory nerve so that our brain detects the sound.

Video 4.3
Hearing

Interactive 4.3
The human ear

Hearing

The ear is a highly sensitive and accurate system. In only a few milliseconds it can collect, transfer, detect and interpret sound. Our ears consist of three main parts, which are the:

> outer ear, where sound waves are collected
> middle ear, where the sound is amplified
> inner ear, where sound is changed into an electrical signal and sent along the hearing, or auditory, nerve.

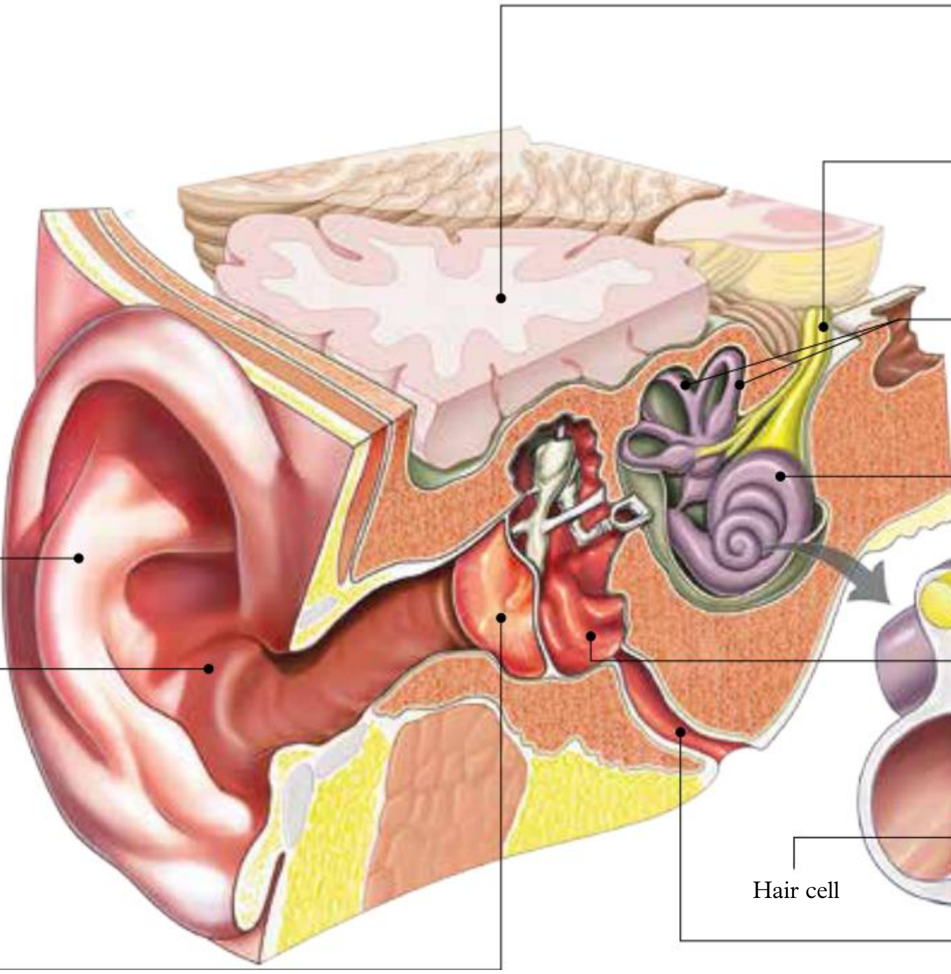
Our ears hear a sound when the vibration of air particles is funnelled down the ear canal by the ear flap, or auricle, which in turn passes the movement on to the ossicle bones in the middle ear. These three small bones vibrate against the oval window at the entrance of the inner ear or cochlea. The fluid in the cochlea sends waves that are detected by the hairs attached to the auditory nerve. This sends a message to the brain, where it is decoded so the sound is recognised.

Figure 1 The main parts of the ear

Ear flap (auricle)
The ear flap (auricle) is made of spongy tissue called cartilage. (The same tissue is in your nose.)

Ear canal
The ear canal contains fine hairs and some wax. Sound waves enter here and cause the air in the canal to vibrate right down to the thin skin covering the end of the tube. This thin skin is called the eardrum.

Eardrum
When hit by the sound waves, the eardrum vibrates at the same rate as the sound waves coming in.



EXPERIMENT
4.3: Why do we need two ears?
Go to page **194**.

4.3 Check your learning

Remember and understand

1 **Describe** the role of the following parts in the hearing process: receptor cells, ossicles, eardrum, auditory nerve, Eustachian tube.

2 True or false?

- **a** The outer ear is used to detect sound.
- **b** The middle ear contains little bones called ossicles.
- **c** The inner ear is protected by a bone in the shape of a spiral seashell.
- **d** The hair cells in the hearing system are found on the scalp of the head.

Apply and analyse

3 Imagine you could not hear at all. **Explain** how it might affect your safety, communication and ability to locate objects. **Explain** how you might feel when you meet someone who can sign Auslan (Australian sign language).

4 **Explain** how damage to the eardrum can affect your ability to hear.

5 Doctors warn about poking cotton buds into our ears to remove wax from our ear canal. They suggest that it is best to remove wax only from the very outer part of the ear and to see a doctor to remove other excess wax. **Explain** why doctors might give this warning.

6 **Identify** how many bones form the ossicles. Determine the names of these bones.

7 **Explain** why an ear infection can sometimes make you feel unbalanced.

Brain
The incoming sound is checked in the auditory cortex against other stored sounds to decide what the sound is. The brain then sends messages to other parts of the the brain associated with that particular sound.

Auditory nerve
The auditory nerve (hearing nerve) carries all of the information about the sound signals coming out of the receptor cells to the brain.

Semicircular canals
The semicircular canals are a set of tubes attached to the cochlea. These tubes are not part of the hearing system; they help us to keep our balance. The canals are filled with fluid. When you move around quickly, the fluid inside the canals also moves quickly and keeps doing so even after you stop. Detector cells inside the canals send messages to the brain that you are moving, but messages from your eyes tell the brain you have stopped. The conflicting messages make you feel dizzy!

Cochlea
The cochlea, a snail-shaped bone, is the sound detector. It is filled with fluid and tiny hairs attached to receptor cells. The vibrations that pass through the oval window create waves in the fluid in the cochlea. These bend the little hairs that stick out of the receptor cells. The bending sets off an electrical signal along the auditory nerve to which the receptor cells are all connected.

Middle ear
The middle ear contains the ossicles, which are three loosely connected bones. They are the smallest bones in the body. The first little ossicle bone (the hammer) lies on the back of the eardrum. It vibrates when the ear vibrates. The vibrations pass along to the anvil and the stirrup bones. The last little stirrup bone presses against the oval window, which is a thin layer of skin near the entrance to the inner ear.

Eustachian tube
The Eustachian tube keeps the air pressure inside the middle ear the same as the air pressure outside. It can do this because it is joined at the back of the throat behind the nose. When the pressure is not equal on both sides of the eardrum, the Eustachian tube opens to let air move in or out to balance the pressure.

//SCIENCE AS
A HUMAN ENDEAVOUR//

4.4 Ears can be replaced

Your hearing relies on very thin layers of skin in the eardrum, small bones in the middle ear, and fine hairs in the cochlea. These delicate mechanisms can become damaged by loud noises, infections or age.

Sound level meter

The loudness of a sound can seem different to different people. It depends on the frequency or pitch of the sound. To measure it scientifically, we use a sound level meter. Sound level is measured in **decibels** (dB). Decibels were named after Alexander Graham Bell, the inventor of the telephone.

decibel
a unit used to measure the intensity of a sound or the power level of an electrical signal

Tinnitus

Tinnitus is usually described as a constant ringing in the ears. It can be low or high pitched and can be caused by loud noises, infections or drugs. It is occasionally the first sign of hearing loss as a result of age. Exposure to constant loud noise can damage the small hairs in the cochlea. This damage can send confusing messages through the aural nerves, which the brain interprets as the constant noise that characterises tinnitus.

Figure 1 A sound level meter

Hearing aid

A hearing aid is designed to increase the amplitude of sound waves as they move into the middle ear. This makes sounds louder so that the person is more likely to hear them.

Cochlear implant

Figure 2 Professor Graeme Clark led the development of the cochlear implant.

Until the 1970s, no one believed that anything could be done to restore the hearing of people with profound deafness due to nerve damage. With the invention of the silicon chip and advances in electronics, several scientists began researching how to make a tiny electronic replacement for a damaged cochlea that could do the job of healthy receptor cells.

Professor Graeme Clark and his team at the University of Melbourne took 8 years to develop a prototype, and it was a further 7 years before a commercial cochlear implant – a 'bionic ear' – was available to people with profound nerve deafness.

A cochlear implant has two sections: the internal and the external parts. The internal part of the implant consists of 22 tiny wire electrodes that are surgically inserted inside the cochlea.

The external part of the cochlear implant consists of a tiny computer (the speech processor). The speech processor sits in a small case behind the ear. It has a powerful built-in microphone. The sound of speech is processed by the speech processor computer and converted to electrical signals. The electrical signals are sent by radio waves through the skin into the internal part of the cochlear implant. The electrical signals activate the hearing nerve inside the cochlea and send a message to the

CHALLENGE
4.4: Is school bad for your health?
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brain to indicate that sound has been detected, just as healthy receptor cells would.

Researchers across Australia are in a race to use a similar approach to restore sight. They use a variety of camera-like devices that are attached to headwear such as glasses. The cameras collect visual data from the area in front of the glasses and convert it to electrical impulses that can be sent into the visual part of the brain. Over time, the brain learns to interpret these signals as a picture, allowing the person to 'see' again.

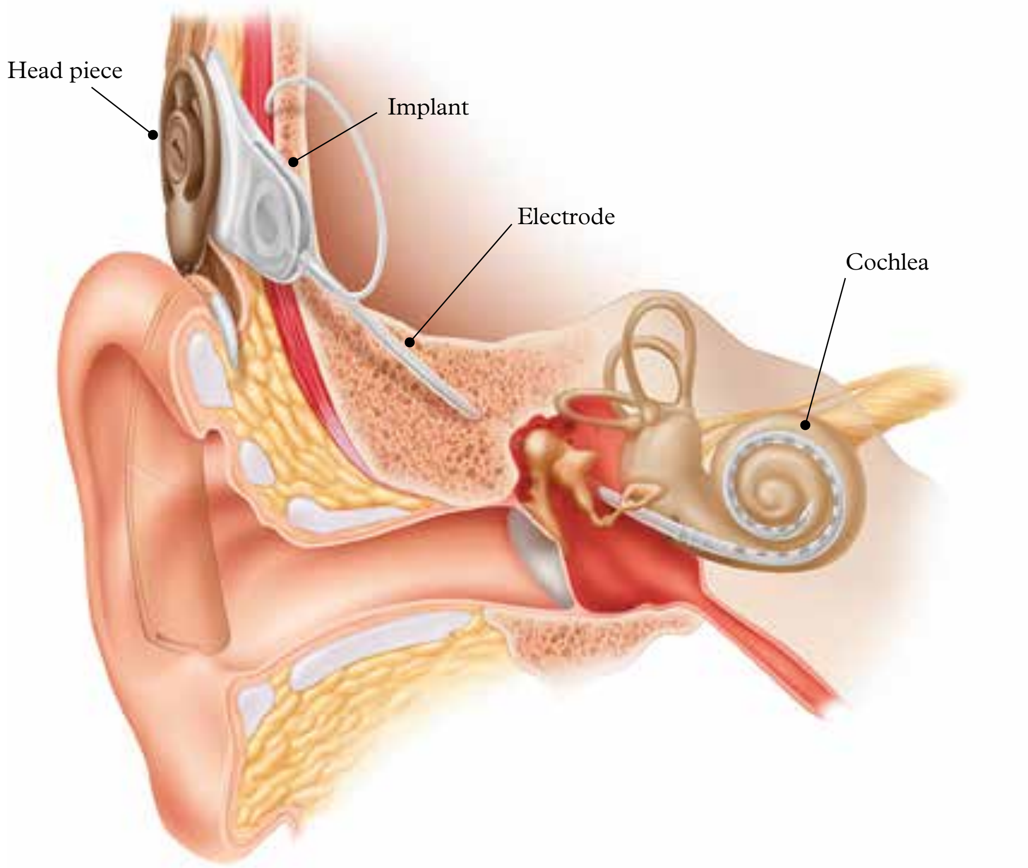

Figure 3 A cochlear implant showing the internal implant that sends the message into the cochlea and the small microprocessor 'head piece' that sits on the outside of the skin.

4.4 Develop your abilities

The ethics of science and technology

While a cochlear implant can allow a person to hear sounds, there is a debate within the Deaf community over the benefit of the implant. There are some members who do not want their hearing to be 'fixed' because they do not consider themselves disabled. Instead they consider the cochlear implant a threat to their unique Deaf culture that uses Auslan (Australian sign language).

1 Explore the ethical viewpoints for each of the individuals of the Deaf community below by describing how a cochlear implant will impact their lives.
   a A one-year-old child with hearing parents who use oral language at home.
   b A one-year-old child with non-hearing parents who use Auslan at home.
   c A fourteen-year-old who has never used Auslan and has suddenly lost their hearing.
   d A fourteen-year-old who has Deaf parents, uses Auslan at home and has suddenly lost their hearing.

Figure 4 Auslan is the name for Australian sign language.

4.5 Visible light is a small part of the electromagnetic spectrum

In this topic, you will learn that:

- light moves in an electromagnetic transverse wavelike motion.
- all electromagnetic waves travel at the same speed through a vacuum.
- light also behaves like a particle called a photon.

transverse wave
a type of (light) wave where the vibrations are at right angles to the direction of the wave

Ancient civilisations believed that light was emitted from the eye and this enabled us to see. We now know that light comes from other sources and that we see objects by light bouncing off them and hitting our eyes.

Like sound, light is a form of energy, which can behave like a wave. There are many different types of light, with a very wide range of wavelengths. Together, these forms of light are called the electromagnetic spectrum.

Electromagnetic spectrum

The electromagnetic spectrum includes the energy that provides music on your radio, the picture on your television, and the heat to cook popcorn in your microwave.

We only see a small amount of this light energy. All of these different types of light have common features. They all travel at the same speed, the speed of light, but they have an obvious difference. They have different wavelengths and therefore different frequencies.

Transverse waves

Light waves are different from sound waves. Sound waves exist as longitudinal waves – the vibrations of the air particles are parallel to the direction of travel of the wave. In light waves, the vibrations are at right angles to the direction of travel of the wave. We call these waves **transverse waves**.

The distance between two neighbouring peaks (rises) on a transverse wave is called the wavelength. It is the same as the distance between two consecutive troughs (dips) or between any two consecutive matching points on the wave. At a different wavelength, the nature of the light wave changes. In the region of visible light, this change of wavelength is seen as different colours.

Because light waves have different wavelengths, they also have different frequencies. As with sound waves, the frequency of a light wave is a measure of the number of waves that pass a point each second

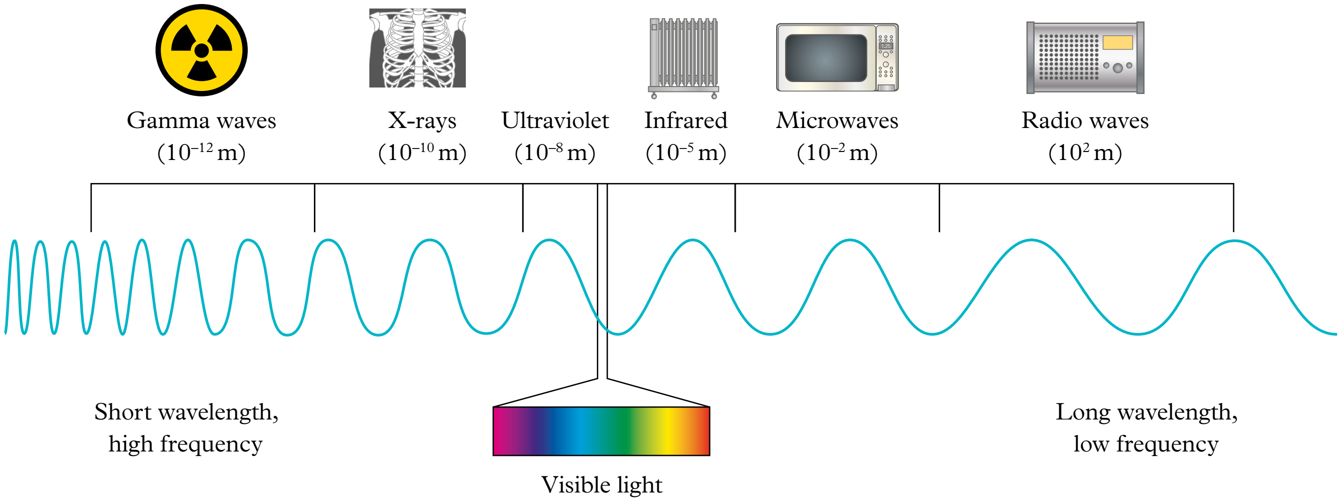

Figure 1 The electromagnetic spectrum

CHALLENGE

4.5: Modelling light waves
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(unit Hz). As the wavelength becomes shorter, more waves can pass a point each second. This means short wavelengths have high frequencies. Like sound, amplitude is a measure of how far a particle moves from its place of rest.

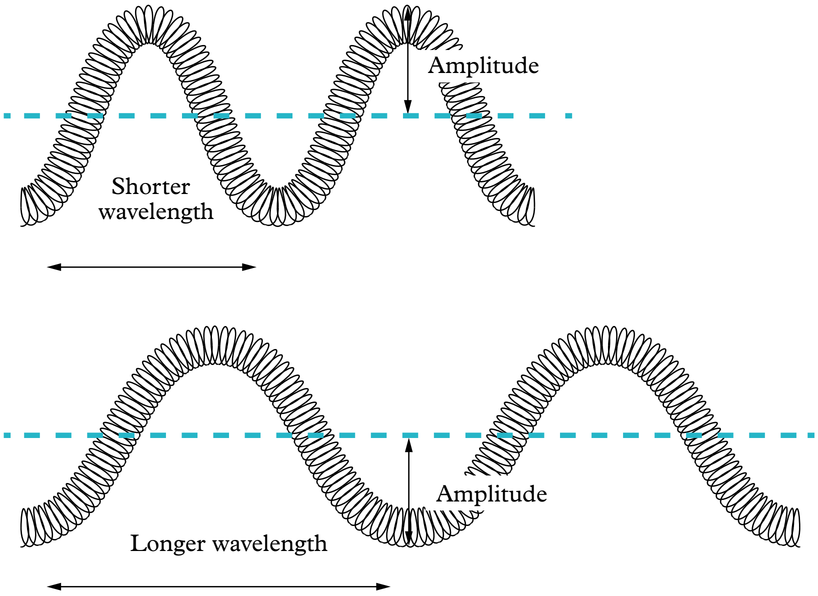

Figure 2 The wavelength of a wave is measured from any point on the wave (usually a peak or trough) to the next corresponding point.

Speed of light

Light waves travel extremely fast: 300 000 km/s in a vacuum. This value is known as the speed of light. The speed of light is much faster than sound, which is why you will always see the light from lightning before you hear the sound of the thunder. Light waves can travel through other media such as air, water and glass, where they slow down slightly. Unlike sound waves, light waves don't need a medium (solid, liquid or gas) in which to travel, due to their electromagnetic nature. They don't pass their energy from atom to atom like sound waves do. This means the different forms of light can travel through space to reach us on Earth.

Particle or wave?

Experiments by early scientists provided two forms of evidence about how light behaves. In some experiments, light behaved as if it were a wave. Other experiments indicated that light was a particle. Scientists now agree that light consists of a particle called a photon, which can move in a wavelike fashion. Just like a wave of water, it can bounce or reflect off surfaces and slow down if it travels through a thicker, denser material. Just like a separate particle, it can move by itself through space. This is how the light from the Sun can reach the Earth.

4.5 Check your learning

Remember and understand

1 **Identify** the unit used to measure wavelength.

2 The frequency of a wave is measured in units called hertz (Hz). **Describe** the relationship between a hertz and the unit of time, the second (s).

3 **Explain** why you see lightning before you hear thunder.

Apply and analyse

4 **Contrast** sound waves and light waves.

5 The relationship between wavelength and frequency is described as an inverse or reciprocal relationship. **Explain** the term 'inverse or reciprocal' as it is used in this statement.

6 Sound is a wave, but sound cannot travel through a vacuum (empty space). Light can travel in a vacuum. **Contrast** sound and light to explain these two statements.

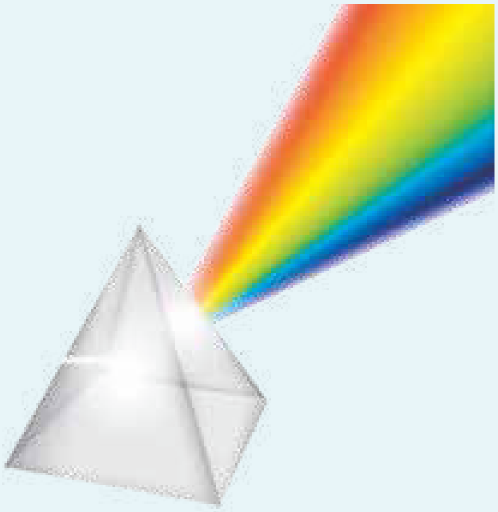

Figure 3 A prism is a transparent object in the shape of a triangle that separates white light into the colour spectrum.

SKILLS LAB
4.6A: Using a Hodson light box
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EXPERIMENT
4.6B: Reflection from plane mirrors
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4.6 Light reflects off a mirror

In this topic, you will learn that:

- light can travel through transparent objects and is blocked by opaque objects.
- translucent objects allow some light energy through.
- when light is reflected off a mirror, the angle of incidence is equal to the angle of reflection (law of reflection).
- the image in the mirror is called a virtual image.

transparent
allowing all light to pass through, so objects can be seen clearly

translucent
allowing light through, but diffusing the light so objects cannot be seen clearly

opaque
not allowing light to pass through

image
a likeness of an object that is produced as a result of light reflection or refraction

normal
(in relation to light) an imaginary line drawn at right angles to the surface of a reflective or refractive material

angle of incidence
the angle between an incident ray and the normal (a line drawn at right angles to a reflective surface)

angle of reflection
the angle between a reflected ray and the normal (a line drawn at right angles to a reflective surface)

virtual image
an image that appears in a mirror; it cannot be captured on a screen

Light can reflect off a glass window but most of the light is transmitted and passes through. This is because the glass in the window is **transparent**. Some types of frosted glass prevent us seeing through them clearly. They are **translucent** because they let some light through but objects cannot be seen clearly. If an **opaque** material is shiny enough or has a shiny coating, it will reflect the light and allow us to see the clear **image**. The best example of this is a mirror.

The reflection of light from a mirror is shown in Figure 1. Light always follows particular rules when it reflects from a surface, no matter how rough or how smooth the surface is. The **normal** is an imaginary line that can be drawn at 90° (or perpendicular) to the mirror's surface. It is usually drawn as a dotted line.

The incident ray represents the incoming light and strikes the mirror at the base of the normal. The **angle of incidence** is the angle between the incident ray and the normal. The reflected ray leaves the mirror from the base of the normal at the same angle as the incidence ray. The **angle of reflection** is the angle between the reflected ray and the normal. An arrow is used to indicate which line is the incident ray and which is the reflected ray. The law of reflection states that the angle of incidence (symbol i) equals the angle of reflection (symbol r).

When we look in a plane mirror (a flat mirror), we see a picture, or image, of ourselves. In the case of a plane mirror the image is always a **virtual image**. This means it cannot be captured on a piece of paper or on a screen as a movie projector does. The image always forms where the light rays cross. The image we see in a plane mirror is also laterally inverted, or flipped sideways.

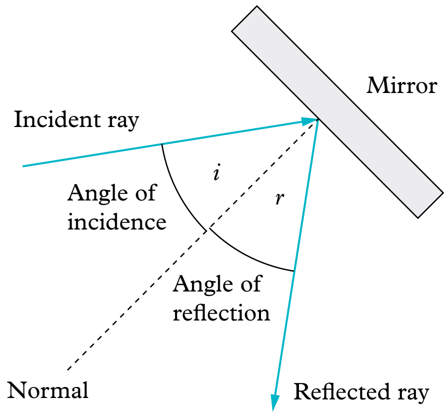


Figure 1 The angle of incidence (i) and the angle of reflection (r) are the same when light reflects off a mirror.

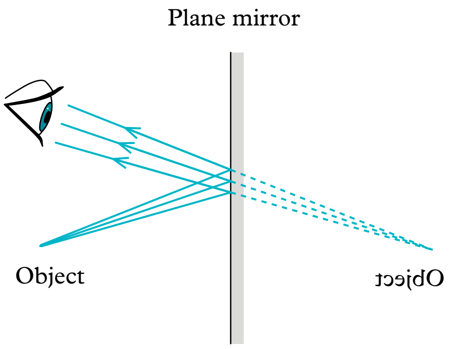


Figure 2 The image in a plane mirror is virtual, laterally inverted, the same size as the object and the same distance from the mirror.

CHALLENGE

4.6C: Mirror writing
Go to page **198**.

CHALLENGE

4.6D: Using curved mirrors
Go to page **198**.

Figure 3 a A mirror shows the lateral inversion of what we look like. **b** Curved mirrors can distort the virtual image.

If we raise our left hand in front of a mirror, our image looks as if it is raising its right hand. The image is also the same distance behind the mirror as the object is in front of it.

Curved mirrors are not as predictable as plane mirrors. They can change the size and nature of the object's image. Curved mirrors can be **convex**, where the centre sticks out, or **concave**, where the centre goes in, like a cave.

Concave mirrors cause the reflected light to bend towards a central point. They are used in reflecting telescopes. Convex mirrors scatter the light of an object. They are typically used in passenger side mirrors.

convex
refers to a lens or mirror that is thicker in the centre than at the ends

concave
refers to a lens or mirror that is thinner in the centre than at the ends

4.6 Check your learning

Remember and understand

1 **Define** (give the meaning of) the terms 'transparent', 'translucent' and 'opaque' and describe one example of each.

2 **Explain** why light fittings are often translucent.

Apply and analyse

3 **Define** the normal, incident ray, angle of incidence, reflected ray and angle of reflection. Use a diagram to illustrate your definitions.

4 **Describe** two uses of convex and concave mirrors.

5 **Compare** (the similarities and differences between) concave and convex mirrors.

6 **Compare** plane mirrors and convex mirrors.

7 **Describe** a virtual image and provide an example of where you would see one.

Figure 4 Virtual or real?

4.7 Light refracts when moving in and out of substances

In this topic, you will learn that:

- refraction is the bending of light as it enters or leaves a denser material at an angle.
- light entering a denser medium bends towards the normal.
- light entering a less dense medium bends away from the normal.

refraction
the bending of light as a result of speeding up or slowing down when moving into a medium of different density

medium
a substance or material through which light can move

refractive index
a measure of the bending of light as it passes from one medium to another

refracted ray
a ray of light that has bent as a result of speeding up or slowing down when it moves into a more or less dense medium

angle of refraction
the angle between a refracted ray and the normal (a line drawn at right angles to a refractive surface)

Refraction

Refraction is the bending of light as it passes at an angle from one transparent **medium** (i.e. substance or material) into another. For example, light bends when it travels from air into water, or from water into air. Often when light is bent or refracted, it can make objects appear distorted. You might be familiar with this effect when light bounces off a spoon sitting in water (see Figure 1).

The amount that light bends depends on the distance between the particles of the medium.

Figure 1 Water refracts light and distorts images.

This optical density or **refractive index** of the material has the symbol n. Water has a higher optical density than air and therefore has a higher refractive index. When a light ray in the air enters water, it slows down and bends closer to the 90° normal. This bent ray is called the **refracted ray** and its angle with the normal is the **angle of refraction**, r.

When the light ray leaves the denser medium (water) and moves into a less dense medium (air), it speeds up. When this happens, the light ray bends away from the normal.

Generally, dense liquids have a higher refractive index than less dense gases. Dense solids have a higher refractive index than less dense liquids. Light bends because it changes speed. The lower the refractive index, the faster the light travels in the medium.

The only time that light does not refract is when it enters a new medium along the normal (90° to the surface). It still changes speed, but there is no bending of the light.

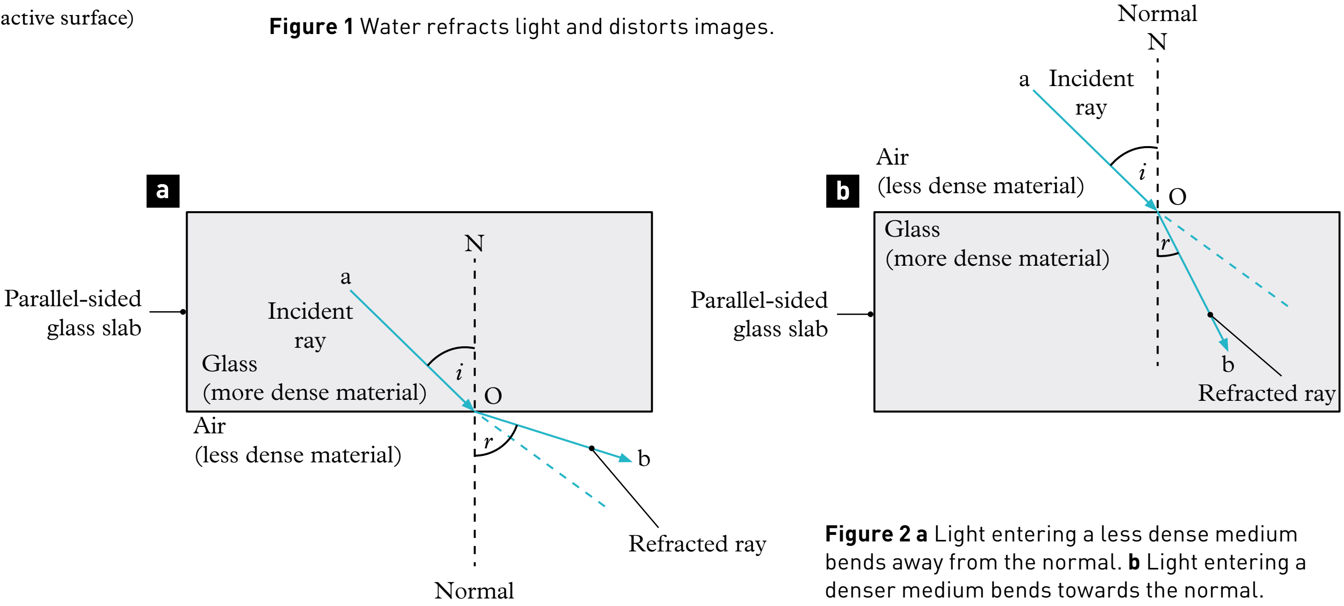


Figure 2 a Light entering a less dense medium bends away from the normal. **b** Light entering a denser medium bends towards the normal.

EXPERIMENT

4.7A: Bending of light
Go to page **199**.

EXPERIMENT

4.7B: Creating images with convex lenses
Go to page **200**.

Figure 3 Swimming pools and the ocean look shallower than they really are. The depth we see is the apparent depth. This person looks shorter in the water because the light bends as it leaves the water making the bottom of the pool appear closer.

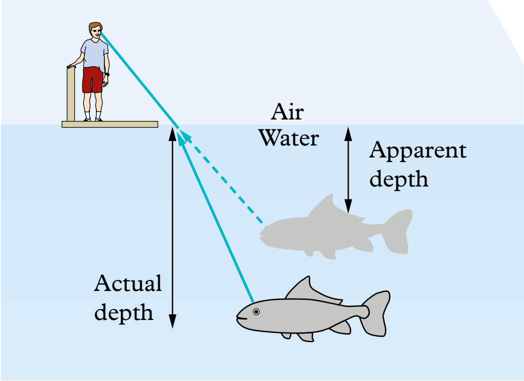


Figure 4 Refraction makes underwater objects appear closer to the surface than they really are. The fish looks closer to the surface than it really is because the light has left a denser medium.

Refraction in everyday life

Refraction explains a lot of everyday phenomena (see Figures 3 and 4).

Lenses

A **lens** is usually a curved piece of transparent material, such as glass or plastic. Convex lenses are thicker in the centre than at the edges and concave lenses are thinner in the centre than at the edges. They work in a similar way to convex and concave mirrors.

Convex lenses cause light rays to **converge**, or focus. The **focus** (or focal point) is the point where the rays cross. The **focal length** is the distance from the focus to the middle of the lens (see Figure 5).

Concave lenses cause light rays to **diverge** or spread out. The light rays appear to cross or focus on the other side of the lens. To find the focus, the diverging rays are followed back until they cross at the apparent light source (see Figure 6). The focus can therefore be described as a **virtual focus** because the light rays do not really come from this point.

lens	a curved piece of transparent material
converge	(in relation to rays of light) to come together at a single point
focus	the point where rays of light cross
focal length	the distance between the centre of a lens and the focus
diverge	(in relation to rays of light) to move away from each other
virtual focus	the point at which a virtual image appears

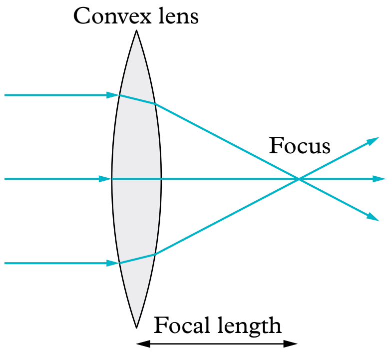


Figure 5 Parallel rays converge to a focal point with convex lenses.

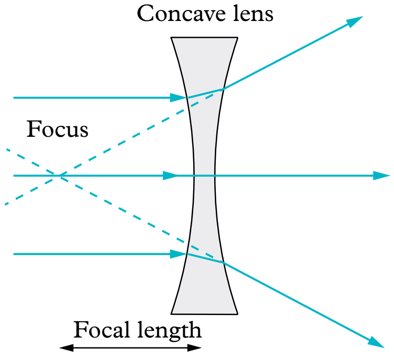


Figure 6 Parallel rays diverge from a focus through concave lenses.

4.7 Check your learning

Remember and understand

1 **Compare** (the similarities and differences between) reflection and refraction.

2 Complete the following sentences by choosing 'towards' or 'away from'.

- **a** Light travelling from a high refractive index to a low refractive index will bend (towards/away from) the normal.
- **b** Light travelling from a low refractive index to a high refractive index will bend (towards/away from) the normal.

Apply and analyse

3 The refractive index of water is 1.33 and that of diamond is 2.42. Draw a diagram to show how a light ray bends when it travels from water into diamond. Remember to use arrows to show the direction the light is moving.

4 The refractive index of glass is 1.52 and that of air is 1.00. Draw a diagram to show how a light ray bends when it travels from glass into air.

5 **Describe** how convex and concave lenses are used.

6 **Contrast** how light moves through convex and concave lenses.

4.8 Different wavelengths of light are different colours

In this topic, you will learn that:

- visible light can be separated (dispersed) into the colours of the visible spectrum – red, orange, yellow, green, blue and violet.
- each colour has a different wavelength and will refract different amounts to produce a rainbow.
- an object appears coloured when some wavelengths are absorbed, and others are reflected into our eyes.

primary colours of light
the three colours of light (red, blue and green), which can be mixed to create white light

secondary colours of light
the colours of light (magenta, cyan and yellow) that result from the mixing of two primary colours of light

visible spectrum
the variety of colours of wavelengths of light that can be seen by the human eye

dispersion
the separation of white light into its different colours

White light can be separated into an infinite range of different colours and shades, but there are generally considered to be six (or seven) basic colours – red, orange, yellow, green, blue and violet. Sir Isaac Newton discovered this concept, and popular belief has it that he included a seventh colour for good luck, called indigo, between blue and violet. This makes the colour sequence easy to remember as 'ROY-G-BIV'. This range of colours is called the **visible spectrum**. The process used to produce these colours is called **dispersion**.

Each colour of the visible spectrum has a different wavelength (the length of one complete cycle of a wave) and is refracted by a different amount when moving through mediums of different densities. This produces the separation of colours. A rainbow is an example of dispersion (and total internal reflection) where the white sunlight is separated (dispersed) into the separate colours. Three of the six basic colours are called the **primary colours of light**. These are red, green and blue. This is because these three colours can be mixed to produce white light. When two of the primary colours are mixed, they form **secondary colours of light**. Red light and blue light make a red-blue light called magenta. Blue light and green light make an aqua or turquoise light called cyan. Green light and red light make yellow light. These rules are different for paints, so if you are an art student, you will need to think differently when considering mixtures of light compared to mixtures of paint!

If cyan light and red light are mixed, the result is white. When only two colours are needed to make white light, they are called complementary colours of light. This is because the cyan light already contains blue and green, so if we add red light, we effectively have the three primary colours, which we already know make white.

Figure 1 A rainbow shows all of the colours in the visible spectrum.

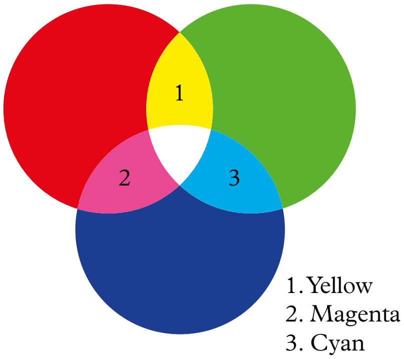


Figure 2 Where the red, green and blue lights overlap, white light is produced. The secondary colours are formed by the overlap of two of the primary colours.

EXPERIMENT

4.8: What colour is it?
Go to page **201**.

Colour of opaque objects

So, why do coloured objects appear coloured? When white light (or sunlight) falls on an opaque object, the energy of some colours may be reflected while others are absorbed (or soaked up or subtracted from the white light). The colour the object appears to be depends on the mix of colours that reflect into our eyes. In most cases, it is easier to consider white light as just made up of red, green and blue light energy.

If some energy colours are absorbed and some are reflected, the object will appear to be the colour of the mix it reflects. This rule is the same for objects illuminated by coloured light. So, a red top appears red because red light is reflected from the red surface to our eye. Grass is green because the red and blue wavelengths are absorbed and the green wavelength is reflected back to our eyes.

Colour of transparent objects

Transparent objects, such as the coloured **filters** in the Hodson light box kits (see Experiment 4.8), or coloured cellophane, **transmit** (allow to pass) and absorb colours in the same general way that blue objects appear blue to us. If the blue colour is transmitted (passes through) while the red and green colours are absorbed, then the filter appears to be blue. Alternatively, a red filter appears red because the blue light and green light are absorbed and red passes through. Therefore, we see the red light from the filter.

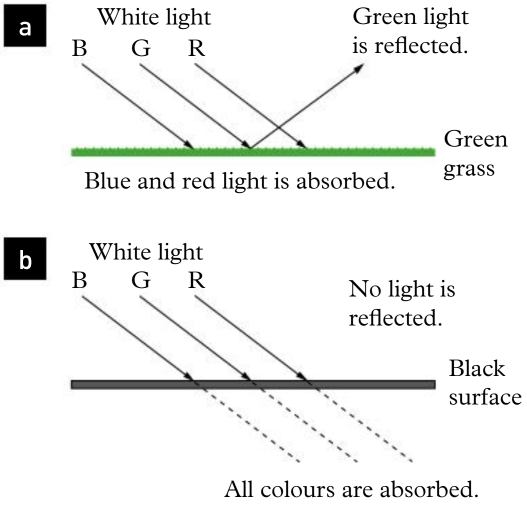


Figure 3 a A green surface reflects green light and so looks green. **b** A black surface absorbs all colours and so looks black. No colours are reflected.

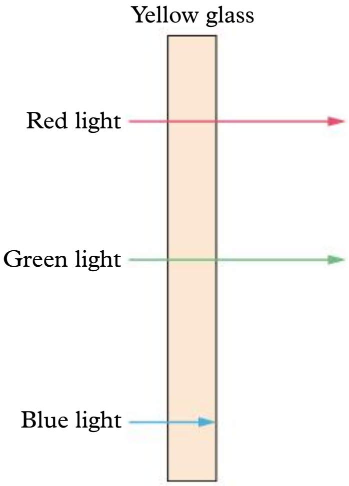


Figure 4 A filter that transmits red and green light and absorbs blue light will appear yellow (the secondary colour that comes from red and green).

filter
a transparent material that allows only one colour of light to pass through

transmit
to allow light to pass through

4.8 Check your learning

Remember and understand

1 **Identify** the colour that is produced when magenta and yellow lights are mixed.

2 **Describe** the colour that a green surface will appear in red light. **Justify** your answer by explaining what happens when the red light hits the green surface.

3 **Contrast** how light moves when hitting a filter or an opaque object.

Apply and analyse

4 **Describe** what you would see if you looked at white light through a yellow filter. **Justify** your answer (by describing what happens to each of the primary colours of the white light when they hit the yellow filter).

5 **Contrast** the primary and secondary colours of light.

6 If white light is a mixture of all the primary colours of light, **explain** what black is.

Figure 5 The colour of light

4.9 The electromagnetic spectrum has many uses

In this topic, you will learn that:

- total internal reflection occurs when a light ray passes into a less dense medium at a particularly large angle.
- optic fibres use total internal reflection to pass data.
- other forms of the electromagnetic spectrum, such as microwaves, are used for communication and for cooking food.

Video 4.9
The electromagnetic spectrum

Total internal reflection

Many optical instruments, such as cameras, microscopes and some telescopes, use lenses, but several use prisms to reflect light. A prism is a block of glass. When light passes from one medium (glass) to a less dense medium (air), it is refracted away from the normal. As the angle of the light (incidence) increases, the refracted ray may be refracted away from the normal so much that it travels at an angle of 90° to the normal. This means the refracted ray moves along the surface edge between the two media, known as the interface. The angle of incidence at which this occurs is called the **critical angle** (symbol i_c).

If the angle of incidence is increased more than the critical angle, the light has nowhere to go and is reflected back into the dense medium. This phenomenon is known as **total internal reflection**. This only occurs when light attempts to travel from a more dense medium (glass) into a less dense medium (air) and only for angles greater than the critical angle.

critical angle
the angle of light that causes the reflected ray to move along the edge between two materials

total internal reflection
the complete reflection of a light ray when it passes from a more dense to a less dense material at a large angle; the ray is reflected back into the dense medium

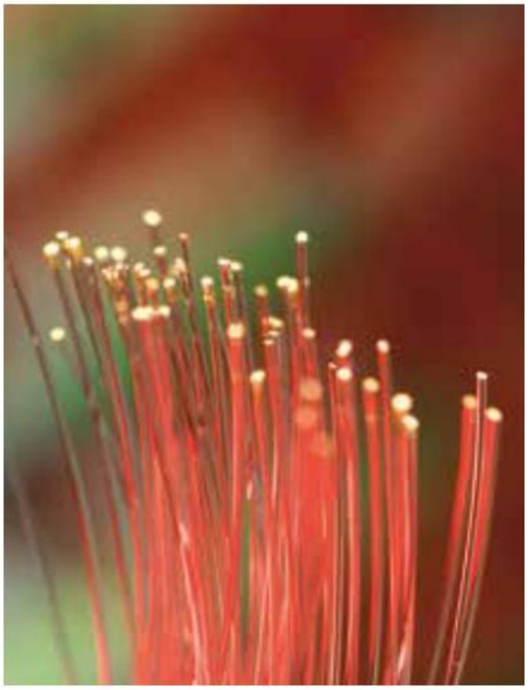


Figure 2 Optic fibres are used to carry digital light signals and have various applications.

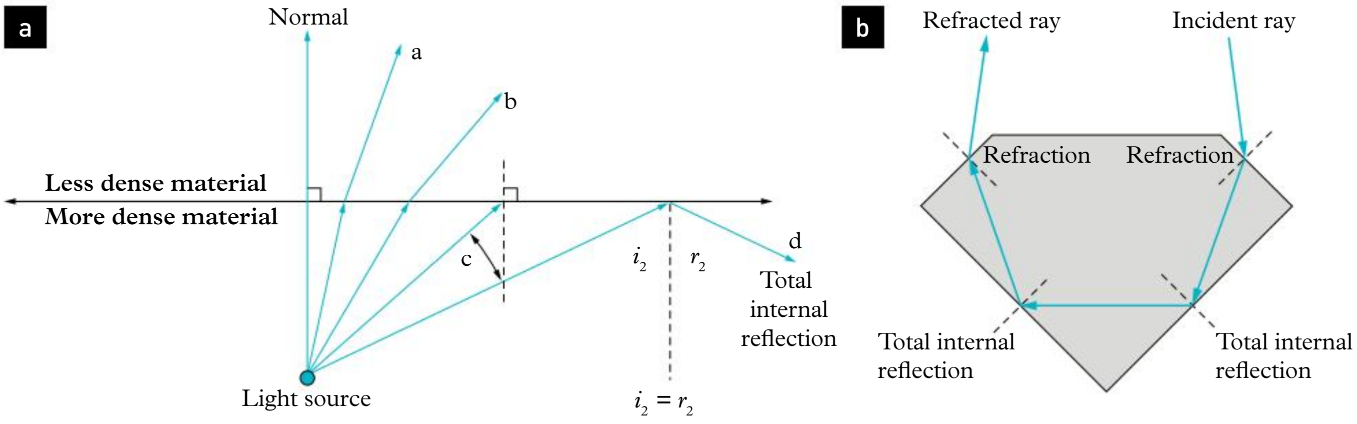


Figure 1 a Rays a and b are refracted because the angle of incidence is less than the critical angle. Ray c occurs when the critical angle is reached. Ray d is reflected when the angle of incidence is greater than the critical angle. **b** Total internal reflection

EXPERIMENT

4.9: What is the wavelength of a microwave?
Go to page **202**.

Using total internal reflection

Optic fibres have revolutionised communication systems. Instead of relying on copper wires to carry electrical signals, we now use bundles of optic fibres to carry light signals for landline telephone calls, the internet and the NBN (National Broadband Network). An **optic fibre** is a very thin fibre of glass or plastic that carries light that reflects (total internal reflection) off the internal surface continually. By sending the information as controlled pulses of light, a single fibre less than a millimetre wide can carry thousands of landline telephone calls and millions of bits of data.

The advantages of optic fibres over copper wire are less signal loss, greater carrying capacity and immunity to electromagnetic interference. This means long distances can be covered with fewer repeater (or booster) stations. A single optic fibre carries much more data than a copper cable, so optic fibres save space, and crossed messages (a form of interference) cannot happen. Optic fibres do not generate heat like the current in a copper wire and are non-electrical, so they don't pose a fire risk and can be used around high voltages.

Microwaves

Microwaves are one small part of the electromagnetic spectrum. The wavelengths of microwaves are usually 1 mm to 1 m in length. Microwaves have many uses from communication (mobile phones) to cooking, from global positioning systems (GPS) to radar. Microwaves can be focused into narrower beams than radio waves. This allows them to be used for person-to-person communication on Earth or even between Earth and the space station.

Microwave ovens

The electromagnetic waves in a microwave oven provide energy to make the water molecules in food move. The increased movement (kinetic energy) of the water molecules causes friction between the other molecules in the food. This friction between all the molecules causes the food to heat up.

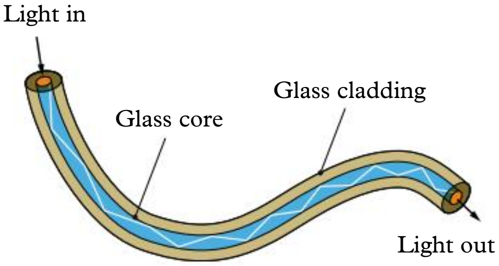


Figure 3 Light zigzags along inside an optic fibre at the boundary of the core and the cladding.

optic fibre
a thin fibre of glass or plastic that carries information/data in the form of light

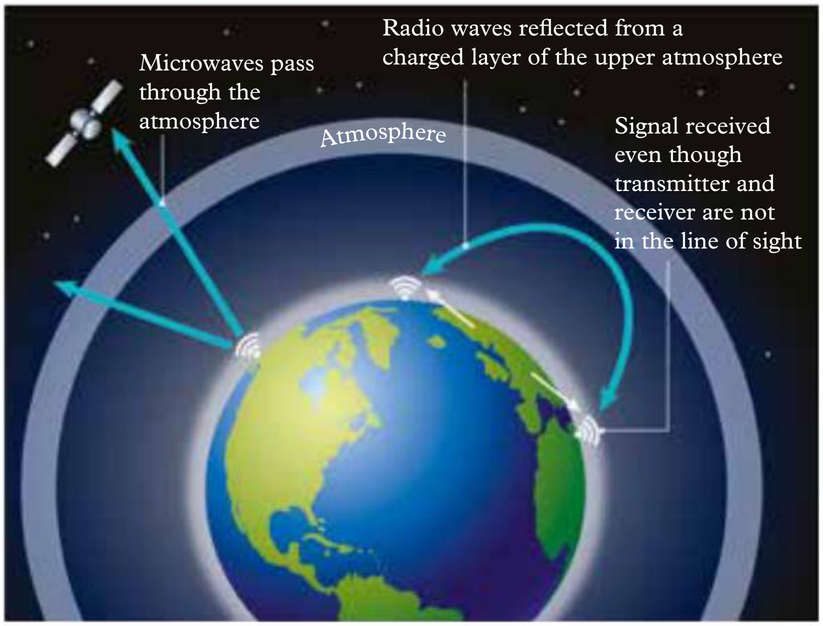


Figure 4 Electromagnetic waves with different wavelengths behave differently in the Earth's atmosphere.

4.9 Check your learning

Remember and understand

1 **Describe** when and how total internal reflection occurs.

2 **Describe** why optic fibres are better for telecommunications than copper wire.

Apply and analyse

3 **Explain** why the amount of water in a food is important when cooking in a microwave.

4 **Contrast** total internal reflection and the reflection from a plane mirror.

5 **Explain** why total internal reflection cannot occur for light passing from a less dense material into a denser material.

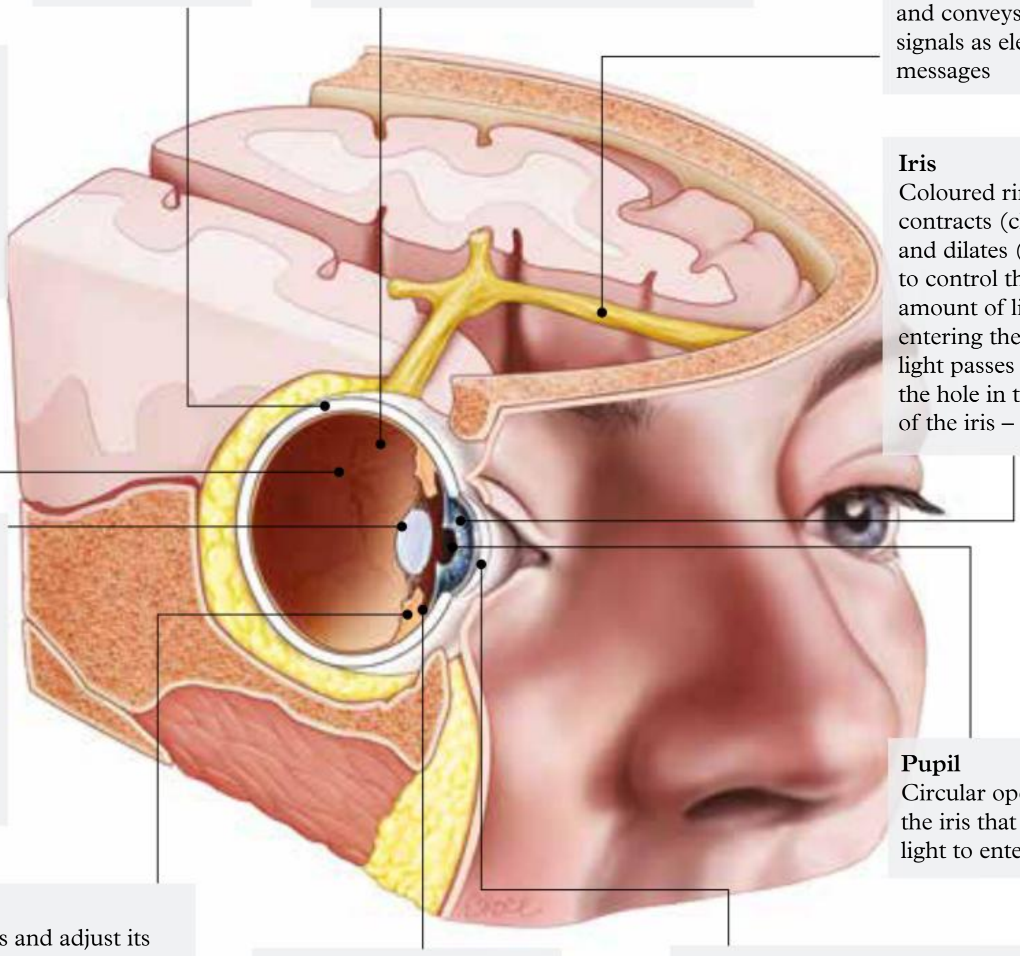
6 **Investigate** one other use for other forms of electromagnetic waves.

4.10 Our eyes detect light

In this topic, you will learn that:

- the iris controls the amount of light entering the eye.
- the cornea and lens focus the light onto the back of the eye (retina).
- the light receptors detect light and send a message to the brain, which then forms a picture.

Figure 1 The human eye



Sclera
Tough, white outer layer of eyeball

Retina
Light-sensitive back section of the eye that contains over a million rods and cones: sensory cells that convert light signals into electrical messages

Optic nerve
Nerve that connects the retina to the brain and conveys the light signals as electrical messages

Vitreous humour
Transparent material inside the eyeball, behind the lens. It is jelly-like in consistency and gives the eyeball its rounded shape.

Iris
Coloured ring that contracts (closes) and dilates (opens) to control the amount of light entering the eye. The light passes through the hole in the centre of the iris – the pupil.

Lens
Curved, transparent structure that further bends the light rays after passing through the cornea and the pupil, to form a focused image on the retina

Pupil
Circular opening in the iris that allows light to enter the eye

Ciliary muscles
These pull on the lens and adjust its shape. Different shapes of the lens allow us to focus on both near and far objects. If the muscles cannot apply the correct forces, then our vision may become blurry and need correcting with spectacles or contact lenses.

Aqueous humour
Watery fluid between the cornea and the lens. Its main function is to provide nourishment for the cornea and the lens.

Cornea
Curved front section of the eye that bends the light rays before they are further bent by the lens. Diseased or cloudy parts of the cornea may be replaced by transplanted corneas from an organ donor.

EXPERIMENT 4.10A: Eye dissection
Go to page 203.

CHALLENGE 4.10B: Vision tests
Go to page 205.

The amount of light entering the eye is controlled by the iris. The iris is the coloured part of the eye and consists of a ring of muscular tissue that expands and contracts, effectively controlling the size of the hole in its centre, the pupil.

This automatic response can easily be tested by shining a bright light into a person's eyes to see if their pupils automatically constrict (shrink). If they don't, the person may have a head injury or an altered state of consciousness.

As light enters the eye, it is bent, or refracted, first by the cornea at the front of the eye and then by the lens. Both of these structures are transparent and curved so they bend the light rays towards each other. Muscles attached to the lens allow it to change shape and adjust the focus of the light from near and far objects. The image produced on the back of the eye, the retina, is upside down (inverted) and smaller than the object (diminished).

The retina contains light-sensitive cells called rods (sensitive to dim light) and cones (sensitive to colour). These cells detect light and convert it into an electrical signal, which is carried to the brain by the optic nerve. The brain then interprets the signals, turning them the right way around and resizing them.

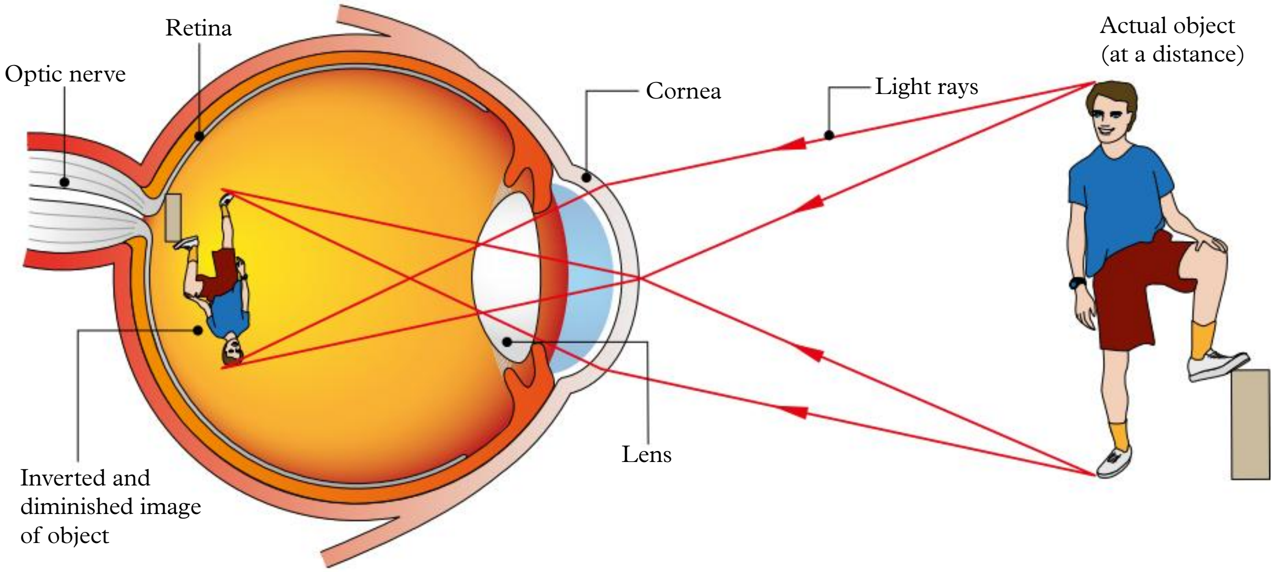


Figure 2 The image produced on the retina is upside down.

4.10 Check your learning

Remember and understand

1 List, in order, the parts of the eye that a ray of light passes through, starting with the cornea and ending with the retina.

2 **Explain** why it is important for the pupil to become smaller in bright light.

3 **Describe** the symptoms that may occur if the ciliary muscles are not working effectively.

4 The lens of the eye can change shape, becoming thicker or thinner in the centre. **Describe** the effect of each of these two changes on the focal length of the lens.

Apply and analyse

5 **Explain** which shape lens (thicker in the centre or thinner in the centre) is needed for our eye to focus on close objects. **Justify** your answer (by describing the effect each lens shape has on the light's focal point, and deciding which would be better for close objects).

6 **Compare** the aqueous humour and the vitreous humour.

4.11

Things can go wrong with our eyes

In this topic, you will learn that:

- hyperopia is when people have difficulty focusing on close objects (long-sighted).
- myopia occurs when people cannot focus on objects that are far away (short-sighted).
- astigmatism occurs when the shape of the eyeball is not spherical.
- cataracts occur when the lens becomes cloudy.

Myopia

If a person can focus on close objects, such as a book or newspaper, but cannot focus on distant objects, they are **short-sighted**. The scientific term for this condition is **myopia**. In this case, the eyeball is too long and the lens focuses the image in front of the retina.

The light rays need to be spread apart (diverged) to refocus the image on the retina. This defect is corrected by using glasses with concave lenses.

Hyperopia

If a person can see distant objects but close objects are blurry, they are **long-sighted**. This is called **hyperopia**. It is caused by the eyeball being too short and the lens focusing the image behind the retina.

The light rays need to be drawn in closer together (converged) to refocus the image on the retina. This defect is corrected by using glasses with convex lenses.

short-sighted
when a person has difficulty seeing distant objects

myopia
short-sightedness; when a person has trouble seeing objects in the distance

long-sighted
when a person has difficulty seeing close objects

hyperopia
long-sightedness; when a person has difficulty seeing close objects

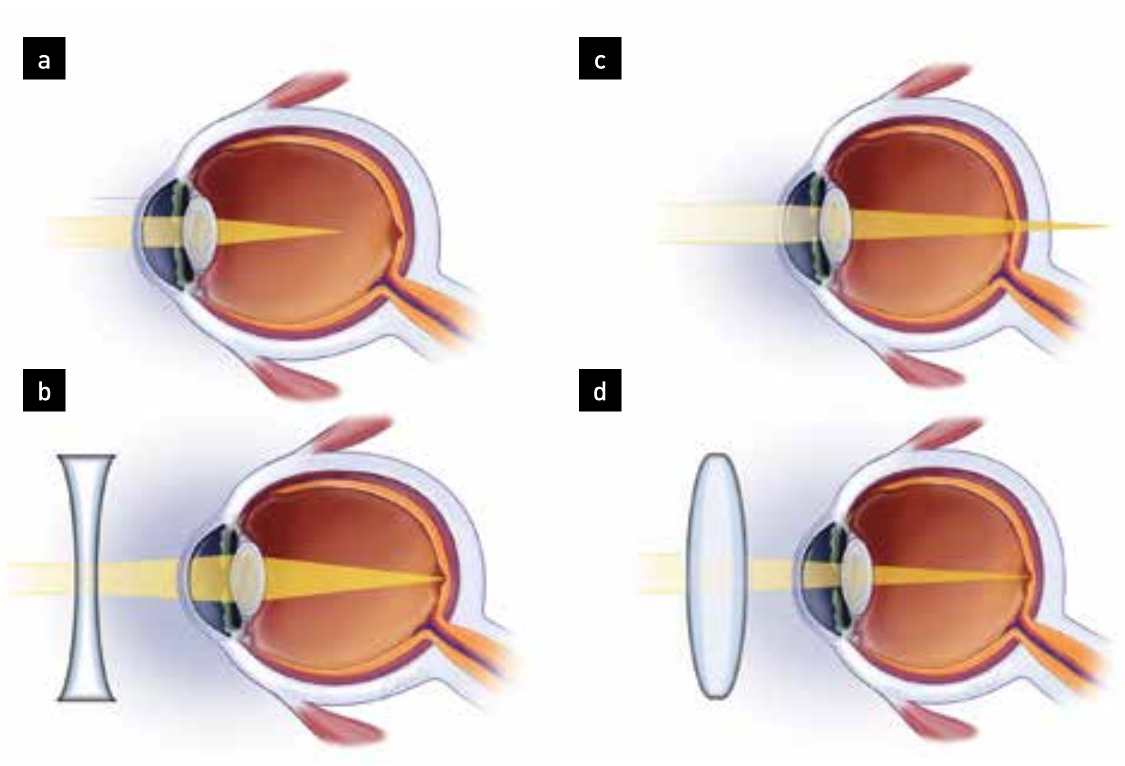


Figure 1 **a** In myopia, the distance vision is blurred because the light rays focus in front of the retina. **b** Myopia is corrected by a concave lens. **c** In hyperopia, the close vision is blurred because the light rays focus behind the retina. **d** Hyperopia is corrected by a convex lens.

CHALLENGE

4.11: Make a jelly lens for your smartphone
Go to page **206**.

Colour-blindness

Another interesting problem is **colour-blindness**. This doesn't mean a person sees in black and white. If the cone cells (that detect the different wavelengths that make up colour) do not function correctly, a person may not be able to tell the difference between certain colours. Red-green colour-blindness is an inherited condition and cannot be corrected with glasses. It is more common in males than females.

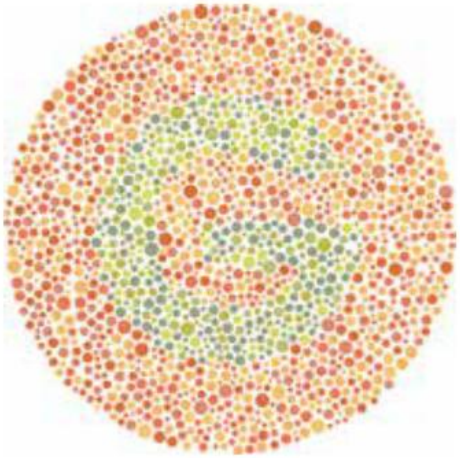


Figure 2 Red-green colour-blind people will not be able to see the letter in this picture.

Cataracts

As you get older, the lens in the eye can start to become cloudy to the extent that it can eventually frost over, like frosted glass. This is called a **cataract** and it can lead to total blindness. The cataract lens can be removed in eye surgery and replaced with a plastic multifocal lens.

Astigmatism

Most people's corneas are curved in the shape of a soccer ball – curved evenly across and up and down. If a person suffers from astigmatism, their corneas are shaped more like an Australian Rules football. In this type of condition, the curvature is different across the cornea from the lengthways curve. This condition leads to an inability to focus correctly and, therefore, blurry vision. It can be corrected with prescription glasses.

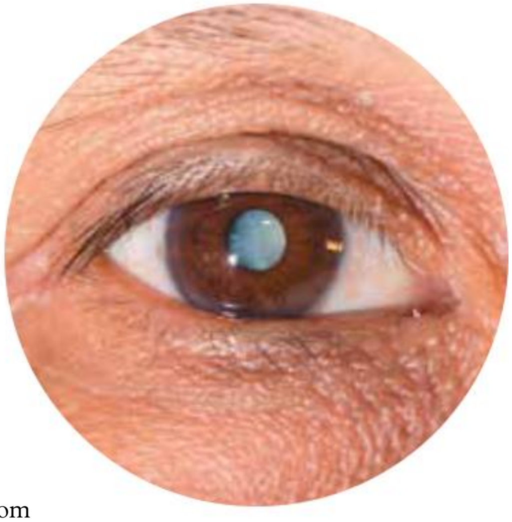


Figure 3 The white film of a cataract prevents light from entering the eye.

colour-blindness
when a person has difficulty identifying different colours; red-green colour-blindness is an inherited condition

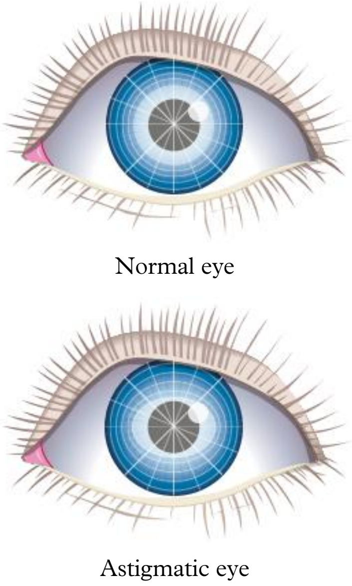


Figure 4 The cornea of a normal eye is round, whereas an astigmatic eye has a football-shaped cornea.

cataract
a cloudiness of the eye lens

4.11 Check your learning

Remember and understand

1 Use a table to contrast short-sightedness and long-sightedness, listing the differences between these two problems and how they are corrected.

2 **Describe** the cause and the effect of each of the following vision difficulties:
  a myopia
  b astigmatism
  c hyperopia.

3 **Describe** how a person who has myopia and astigmatism can have their vision corrected.

Apply and analyse

4 **Describe** the advantages of wearing contact lenses instead of glasses. **Describe** the disadvantages.

5 Ask someone who wears glasses if you can examine them. Carefully try to detect which type of lenses they have. Try the glasses on. **Describe** how they affect your near and far vision. (If you already have glasses, try someone else's.)

6 **Investigate** what is involved in laser eye surgery and write a short report that describes how the behaviour of the eye is changed by this surgery.

REVIEW 4

Multiple choice questions

1 **Identify** which of the following terms can be used to describe sound waves.

- **A** transverse waves
- **B** electromagnetic waves
- **C** microwaves
- **D** longitudinal waves

2 **Identify** which of the following is correct.

- **A** Sound waves travel faster than light waves.
- **B** Sound travels faster in air than in water.
- **C** Light travels faster than sound.
- **D** Sound can travel through space.

3 **Identify** the name of the condition where the eyeball is the shape of an Australian Rules football.

- **A** myopia
- **B** astigmatism
- **C** hyperopia
- **D** cataracts

Short answer questions

Remember and understand

4 Complete this paragraph by inserting the missing words. The first letter of each missing word is given.
Sound is created by v________. The v________ create c________ and r_______ due to the movement of the particles as the sound w_______ passes through. The w_____ travels through the substance and is known as a l_________ wave. The greater the vibration, the higher the v_______ of the sound, which means it sounds l_______. Sound waves must have a m_____ to pass through.

5 The semicircular canals are located in our ears but are not used for hearing. **Describe** the function (what they do) of these structures.

6 **Define** the term 'frequency' of sound. **Identify** its unit.

7 **Explain** why sound travels faster in solids than in air.

8 **Describe** the difference between the primary colours of light and the primary colours of paint.

9 **Compare** transverse waves and longitudinal waves.

10 **Define** the terms 'opaque', 'translucent' and 'transparent'.

11 **Describe** the conditions that can slow the speed of light.

12 **Compare** the reflection of light and the refraction of light.

13 **Describe** how light moves in an optic fibre.

14 **Compare** the amplitude of light waves to the amplitude of sound waves.

15 **Identify** the structures labelled a–e as shown in Figure 1.

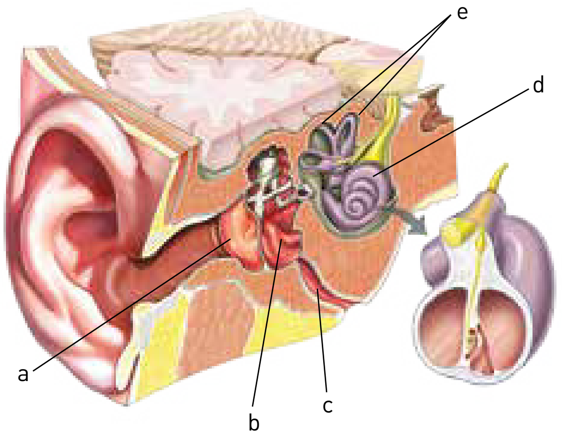


Figure 1 The ear

Apply and analyse

16 **Explain** why astronauts could shout at each other with their helmets touching if the radio communication broke down on the Moon.

17 **Explain** how pitch and frequency of sound are related.

18 **Compare** communication using optic fibres to using copper wires.

19 **Create** a table, listing the parts of the human eye in one column with the function of each part in the second column.

20 Exposure to 85 dB or more of noise for 8 hours is illegal in Australian workplaces. **Explain** the reason for this regulation even though this level of noise is not regarded as 'painful'.

21 **Describe** the appearance of the Australian flag when viewed in:

- **a** blue light
- **b** red light
- **c** green light.

22 Aboriginal and Torres Strait Islander men use the Yidaki, or didgeridoo, for many important ceremonies. **Explain** why longer Yidakis produce sounds that are lower in pitch than short Yidakis. (HINT: consider the length of the sound waves produced by each Yidaki.)

Evaluate

23 Butchers sometimes use red lights to illuminate their meat in the shop window. **Explain** why they might choose this colour.

24 A student claimed that black is not a colour. **Evaluate** their claim (by explaining how an object can appear black, defining what is a colour of light and deciding if the student is correct).

25 A grand piano can be played with the lid open or closed. Most often, concert pianists will play with the lid open towards the audience. **Explain** the effect that leaving the lid off the piano will have on the music the audience will hear.

Social and ethical thinking

26 Many groups of medical researchers are working to improve the current versions of bionic eyes that provide sight to blind people. This research costs many millions of dollars that could be used to treat people with other health problems. **Describe** three reasons why research into bionic eyes is important.

Critical and creative thinking

27 Table 1 shows the speed of sound at different temperatures.

Table 1 Temperature and the speed of sound

Air temperature (°C)	Speed of sound (m/s)
0	330
10	336
20	342
30	348
40	354

a Using graph paper, draw a graph of the speed of sound (vertical axis) at various air temperatures (horizontal axis). Start the scale at 320 m/s on the vertical axis.

b **Describe** what happens to the speed of sound as the temperature increases.

c Use your graph to **identify** the speed of sound at 5°C.

d Use your graph to **identify** the temperature of the air if the speed of sound is 351 m/s.

28 Astronauts in space can still see each other even if they cannot hear each other.

a Use this information to **compare** how light travels to how sound travels.

b **Describe** what this tells us about the ability of light energy to travel through outer space.

29 **Investigate** the differences and similarities between audible sound, ultrasound and infrasound. Display your answer using a Venn diagram.

Research

30 Choose one of the following topics for a research project. A few guiding questions have been provided, but you should add more questions that you wish to investigate. Present your report in a format of your own choosing, but one component of your report must include a demonstration of sound (for example, if you make an instrument, it needs to be played). In a multimedia presentation, sound must be part of the presentation. If you interview someone as part of your research, you must present a taped recording of your interview along with your report.

» Supersonic planes

Identify what 'supersonic sound' means. Contrast a supersonic jet and a normal jet aircraft. Describe one of the problems with supersonic planes. Describe why the Concorde was removed from air travel service.

» Hearing technologies

When a person is first fitted with a cochlear implant it can take some time and practice before they are able to understand what all the sounds mean. Describe what it would be like to wear a bionic ear. Explain why someone fitted with an implant might need time to understand the meaning of words.

» Vision defects

Some people find it difficult to focus on near or distant objects. This type of defect is reasonably common. Identify the causes of both defects and how they can be corrected. Describe some other vision defects and how they are treated.

» Night vision goggles

Night vision goggles allow soldiers to see at night and spot the enemy before they are spotted themselves. They give an army a tactical advantage. Describe how the goggles work. Identify the limitations of these goggles (e.g. will they work in a totally dark environment? Do they have any disadvantages for the soldiers operating them?)

Reflect

The table below outlines a list of things you should be able to do by the end of Chapter 4 ‘Sound and light’. Once you’ve completed the chapter, use the table to reflect on your ability to complete each task.

	I can do this.	I cannot do this yet.
Describe the motion of molecules in a longitudinal wave.	☐	☐ Go back to Topic 4.1 ‘Vibrating particles pass on sound’ Page 66
Explain why sound does not travel through space. Relate the transmission of sound to the density of particles of the medium through which it travels.	☐	☐ Go back to Topic 4.2 ‘Sound can travel at different speeds’ Page 68
Identify the key structures of the ear and describe their function in detecting sound. Describe the processes involved in the detection of sound.	☐	☐ Go back to Topic 4.3 ‘Our ears hear sound’ Page 70
Relate technological and scientific developments with the needs of society.	☐	☐ Go back to Topic 4.4 ‘Science as a human endeavour: Ears can be replaced’ Page 72
List the classes of electromagnetic radiation and their average wavelengths. Explain how light behaves as a wave and how it behaves as a particle.	☐	☐ Go back to Topic 4.5 ‘Visible light is a small part of the electromagnetic spectrum’ Page 74
Describe the characteristics of a virtual image. Demonstrate appropriate use of a Hodson light box.	☐	☐ Go back to Topic 4.6 ‘Light reflects off a mirror’ Page 76
Describe the refraction of light through a convex and concave lens. Explain the difference between focus and virtual focus.	☐	☐ Go back to Topic 4.7 ‘Light refracts when moving in and out of substances’ Page 78
Describe how we see the colour of opaque and transparent objects. Relate the secondary colours of light to the primary colours of light.	☐	☐ Go back to Topic 4.8 ‘Different wavelengths of light are different colours’ Page 80
Define critical angle, total internal reflection and optic fibre. Describe how optic fibres and microwave ovens work.	☐	☐ Go back to Topic 4.9 ‘The electromagnetic spectrum has many uses’ Page 82
Identify the main structures of the human eye and describe their functions. Explain how an image forms on the retina.	☐	☐ Go back to Topic 4.10 ‘Our eyes detect light’ Page 84
Provide examples of disease and problems that affect the eyes and vision.	☐	☐ Go back to Topic 4.11 ‘Things can go wrong with our eyes’ Page 86

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Compete in teams to test your knowledge.

Chapter quiz
Test your understanding of this chapter with one of three chapter quizzes.

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Quizlet Live
Launch a quiz for your students on key concepts in this chapter.

CHAPTER

5

PHYSICAL AND CHEMICAL CHANGE

Why do some chemicals explode?

What if?

Dissolving tablets

What you need:

Effervescent antacid tablets, beaker, water, timer, Vaseline

What to do:

1 Place 100 mL of water in a beaker
2 Place an effervescent antacid tablet in the water and time how long it takes to dissolve.

What if?

- What if warm water was used?
- What if cold water was used?
- What if the tablet was broken up?
- What if more than 100 mL of water was used?
- What if the tablet was covered in Vaseline?

CHALLENGE
5.1A: Classifying elements
Go to page **207**.

5.1

Atoms and elements make up matter

In this topic, you will learn that:

- all matter is made up of atoms.
- an element is a pure substance with one type of atom.
- the periodic table organises elements according to their chemical and physical properties.

Figure 1 Not all metals are the same.

atom
the smallest particle of matter; cannot be created, destroyed or broken down (indivisible)

monatomic
consisting of a single atom

diatomic molecule
a molecule that consists of two atoms

periodic table
a table in which elements are listed in order of their atomic number, and grouped according to similar properties

period
(in chemistry) a horizontal list of elements in the periodic table

What are atoms?

In Year 7 you learnt about the ideas of Democritus and the Ancient Greeks. They used the word *atomos* to describe particles that could not be divided up any further. The concept of the atom was also used in ancient Indian texts. John Dalton and other chemists from the nineteenth century further developed the idea, using the term ‘atom’ to describe those particles that couldn’t be broken down any further by chemical means.

Atoms come in different sizes and masses. The smallest atom is the hydrogen atom. Next is helium. Larger and heavier atoms include lead and uranium.

What are elements?

An element is a pure substance made of only one type of **atom**. All the atoms in the element are identical. For example, the element carbon is only made up of carbon atoms; oxygen is only made up of oxygen atoms.

There are 90 different elements that are found naturally on Earth. Each element is made up of its own type of atom. Another 20 or so atoms have been made artificially, but these are highly radioactive and break down within a second.

Elements cannot be broken down into other substances because they are already the simplest substances. They can be thought of as being ‘elementary’, which is the origin of the name element.

The element is the substance that can be observed and has properties that can be measured. Single atoms are far too small to be observed and are incredibly difficult to measure.

The elements are classified into two main groups: metals and non-metals. In the solid state, atoms of metals are held in a lattice. Most other elements, which are not metals, are called non-metals. Most non-metals are gases at normal temperatures. Some gases, such as neon and helium, are **monatomic**. This means that each gas particle is a single atom (mono = one). However, the atoms in other gases, such as oxygen, hydrogen and nitrogen, are **diatomic molecules**. The atoms of these elements join together in pairs (di = two).

Elements and the periodic table

The **periodic table** arranges all the elements in order of the size of their atoms. It also groups together elements with similar properties. The horizontal rows in the table are called **periods**.

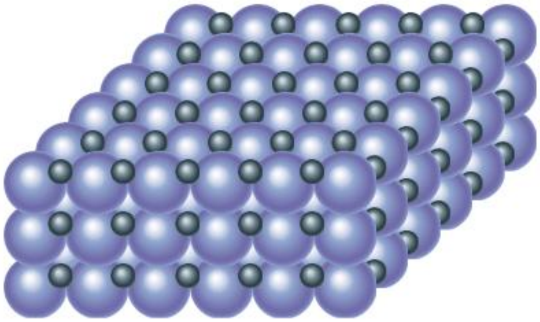


Figure 2 A metallic lattice

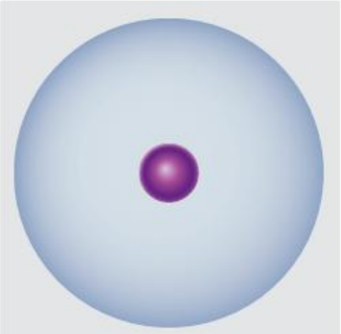


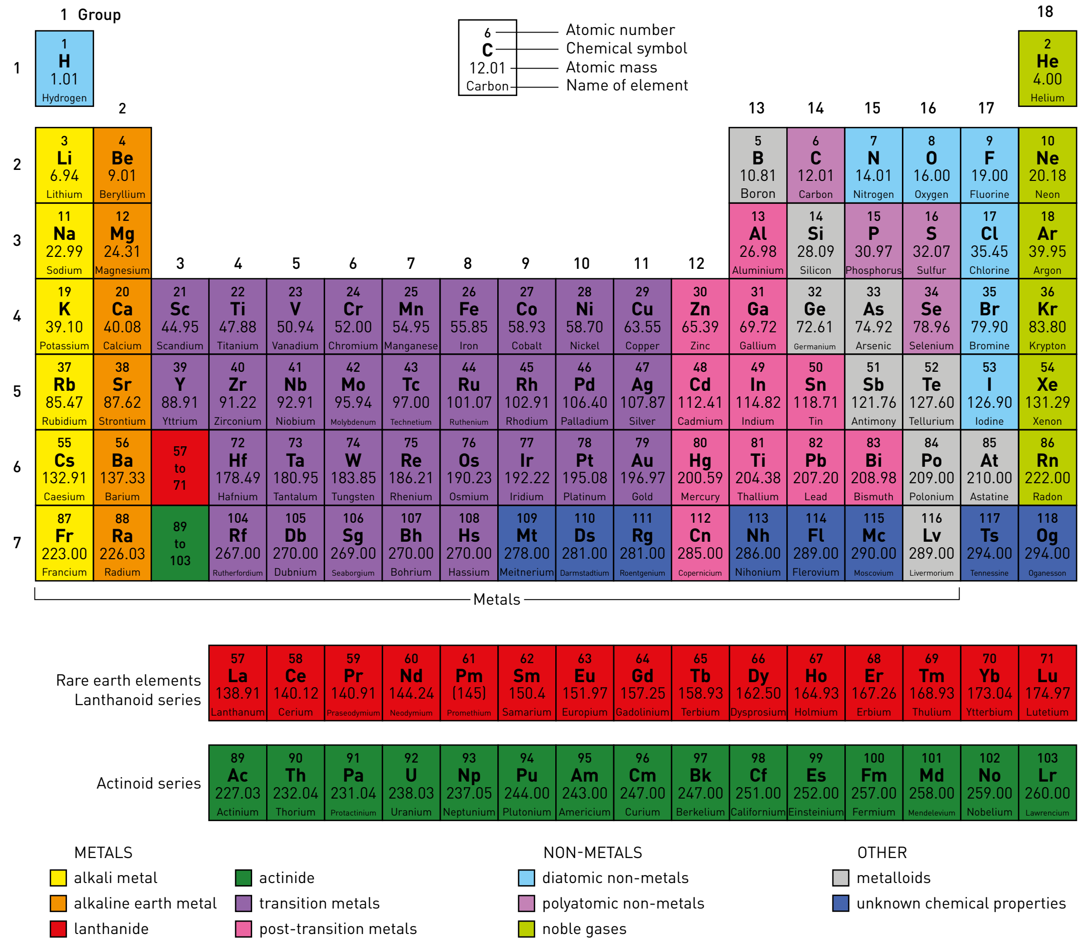
Figure 3 Helium is monatomic.

CHALLENGE

5.1B: Identifying the elements in the periodic table
Go to page **208**.

EXPERIMENT

5.1C: Properties of the elements
Go to page **209**.



	1 Group	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H 1.01 Hydrogen																	2 He 4.00 Helium
2	3 Li 6.94 Lithium	4 Be 9.01 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
3	11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
4	19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.95 Scandium	22 Ti 47.88 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.95 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.70 Nickel	29 Cu 63.55 Copper	30 Zn 65.39 Zinc	31 Ga 69.72 Gallium	32 Ge 72.61 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
5	37 Rb 85.47 Rubidium	38 Sr 87.62 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.94 Molybdenum	43 Tc 97.00 Technetium	44 Ru 101.07 Ruthenium	45 Rh 102.91 Rhodium	46 Pd 106.40 Palladium	47 Ag 107.87 Silver	48 Cd 112.41 Cadmium	49 In 114.82 Indium	50 Sn 118.71 Tin	51 Sb 121.76 Antimony	52 Te 127.60 Tellurium	53 I 126.90 Iodine	54 Xe 131.29 Xenon
6	55 Cs 132.91 Caesium	56 Ba 137.33 Barium	57 to 71	72 Hf 178.49 Hafnium	73 Ta 180.95 Tantalum	74 W 183.85 Tungsten	75 Re 186.21 Rhenium	76 Os 190.23 Osmium	77 Ir 192.22 Iridium	78 Pt 195.08 Platinum	79 Au 196.97 Gold	80 Hg 200.59 Mercury	81 Ti 204.38 Thallium	82 Pb 207.20 Lead	83 Bi 208.98 Bismuth	84 Po 209.00 Polonium	85 At 210.00 Astatine	86 Rn 222.00 Radon
7	87 Fr 223.00 Francium	88 Ra 226.03 Radium	89 to 103	104 Rf 267.00 Rutherfordium	105 Db 270.00 Dubnium	106 Sg 269.00 Seaborgium	107 Bh 270.00 Bohrium	108 Hs 270.00 Hassium	109 Mt 278.00 Meitnerium	110 Ds 281.00 Darmstadtium	111 Rg 281.00 Roentgenium	112 Cn 285.00 Copernicium	113 Nh 286.00 Nihonium	114 Fl 289.00 Flerovium	115 Mc 290.00 Moscovium	116 Lv 289.00 Livermorium	117 Ts 294.00 Tennessine	118 Og 294.00 Oganesson

Rare earth elements Lanthanoid series	57 La 138.91 Lanthanum	58 Ce 140.12 Cerium	59 Pr 140.91 Praseodymium	60 Nd 144.24 Neodymium	61 Pm (145) Promethium	62 Sm 150.4 Samarium	63 Eu 151.97 Europium	64 Gd 157.25 Gadolinium	65 Tb 158.93 Terbium	66 Dy 162.50 Dysprosium	67 Ho 164.93 Holmium	68 Er 167.26 Erbium	69 Tm 168.93 Thulium	70 Yb 173.04 Ytterbium	71 Lu 174.97 Lutetium
Actinoid series	89 Ac 227.03 Actinium	90 Th 232.04 Thorium	91 Pa 231.04 Protactinium	92 U 238.03 Uranium	93 Np 237.05 Neptunium	94 Pu 244.00 Plutonium	95 Am 243.00 Americium	96 Cm 247.00 Curium	97 Bk 247.00 Berkelium	98 Cf 251.00 Californium	99 Es 252.00 Einsteinium	100 Fm 257.00 Fermium	101 Md 258.00 Mendelevium	102 No 259.00 Nobelium	103 Lr 260.00 Lawrencium

Figure 4 The periodic table

The vertical columns are called **groups**. The elements in a vertical group often have similar properties, such as the way they look or how they behave. Metals are found to the left of the grey zigzag line of atoms in Figure 4 and the non-metals are found to the right of the line.

On the periodic table, you will notice that elements are represented by their symbols, which consist of one or two letters: hydrogen has the symbol H; helium has the symbol He. Other symbols are oxygen (O), carbon (C), nitrogen (N), sulfur (S), gold (Au) and silver (Ag). The first letter is always a capital letter, and the second letter (if there is one) is always lower case.

Elements can also be classified based on their chemical properties. These include how they react with other substances, such as acids and the oxygen in the air.

group
(in chemistry) a vertical list of elements in the periodic table that have characteristics in common

5.1 Check your learning

Remember and understand

1 **Compare** the difference between atoms and elements.
2 **Identify** the two large groups in the periodic table.
3 **Identify** the name given to the rows of the periodic table.
4 **Identify** the names and symbols of the first five elements in the periodic table.

Apply and analyse

5 **Identify** the element found in period 3, group 2.
6 **Identify** the two letters that are not represented in the elemental symbols of the periodic table.

Evaluate and create

7 **Create** five words using the elemental symbols of the periodic table. (An example is: Helium (He), Lithium (L) and Phosphorus (P) can spell HeLP.)

5.2 Atoms bond together to make molecules and compounds

In this topic, you will learn that:

- molecules are groups of two or more atoms that are bonded together.
- when the atoms are different elements bonded together, they can also be called compounds.
- elements and compounds can be represented by chemical formulas, while mixtures cannot.

Interactive 5.2
Elements and compounds

Video 5.2
Elements and compounds

What are molecules?

When two atoms are linked or bonded together, they are called **molecules**. Molecular substances can be broken into two groups, those with only one type of atom (**molecular element**), and those with two or more types of atoms (**compounds**). This is summarised in Table 1.

Table 1 Summary of elements and molecules

	1 type of atom	>1 type of atom
1 atom	monatomic element, e.g. He	Cannot exist
>1 atom	molecular element, e.g. O_2	molecular compound, e.g. H_2O

Oxygen is an example of a molecular element. An oxygen molecule consists of two oxygen atoms joined together. Oxygen gas is a substance made of oxygen molecules. Pure oxygen gas consists of millions and millions of oxygen molecules, all exactly alike.

This means that the word 'oxygen' can be used in two different ways: it can be used to describe the element or it can be used as the name of the molecule. When you see the names of chemicals, check the way in which the name is being used.

Molecules of a compound contain atoms of two or more different elements. Carbon dioxide is a **molecular compound**. Its molecules contain one carbon and two oxygen atoms (CO_2). Pure carbon dioxide gas (the substance) consists of millions and millions of carbon dioxide molecules.

Water is another molecular compound. A water molecule is made up of two hydrogen (H) atoms and one oxygen (O) atom. This is why water is referred to as H_2O (see Figure 4). The small numbers (we call them subscript) after an element tell you how many atoms of that element there are. A glass of water consists of many billions of water molecules. The water molecules are all identical.

When sugar ($C_6H_{12}O_6$) is mixed with water (H_2O), there are two different compounds in the **mixture**. Because the two compounds are not chemically bonded to each other, they can be easily separated. This means mixtures cannot be represented by chemical formulas.

Figure 1 Most tablets and capsules are compounds mixed with other substances to help the active ingredients absorb into the blood and reach their desired target.

molecule
group of two or more atoms bonded together (e.g. a water molecule)

molecular element
a molecule that contains two or more of the same atoms bonded together

compound
a substance made up of two or more types of atoms bonded together (e.g. water)

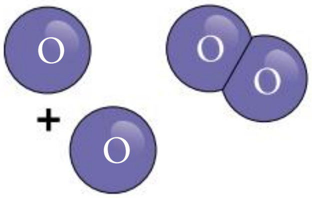


Figure 2 Oxygen (O_2) is a molecular element formed by two oxygen atoms.

Figure 3 Carbon dioxide (CO_2) is a molecular compound made up of one carbon atom and two oxygen atoms.

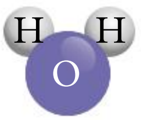


Figure 4 Water (H_2O) is a molecular compound made up of two hydrogen atoms and one oxygen atom.

EXPERIMENT

5.2: Decomposing copper carbonate
Go to page **210**.

Compounds and mixtures

You have seen that elements contain only one type of atom. However, there are far more substances than just the 90 naturally occurring elements.

Most of the substances we use are compounds. By altering the numbers and types of atoms in a substance, chemists can alter its properties. Many substances that are important to our society are used because of their important properties. These compounds are made in factories or obtained from natural products, for example pharmaceuticals and fertilisers.

Some compounds are individual molecules, such as water and carbon dioxide. Other compounds are long strings of atoms called **polymers**. The groups of atoms in these strings repeat over and over – like the beads on a necklace. Plastics are examples of polymers. Other polymers include chemicals found in plants and animals, such as starch and proteins.

Other compounds exist in a lattice arrangement, with atoms held together in three-dimensional networks. This can make them very strong as each atom is held in place by many bonds.

Elements and compounds can be **pure substances**. This means all the particles in the substances are identical to each other. Water is an example of this. Pure water contains many molecules of H_2O (water molecules). The flow chart in Figure 6 shows the different types of substances.

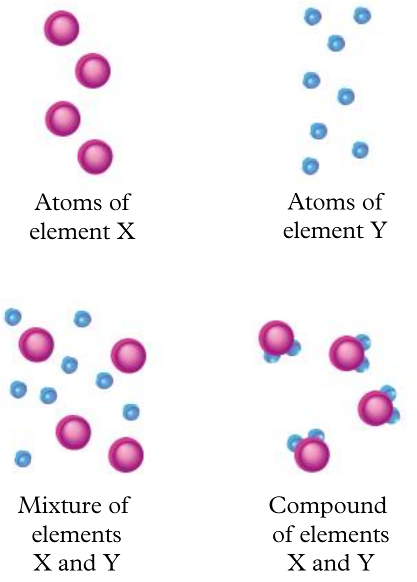
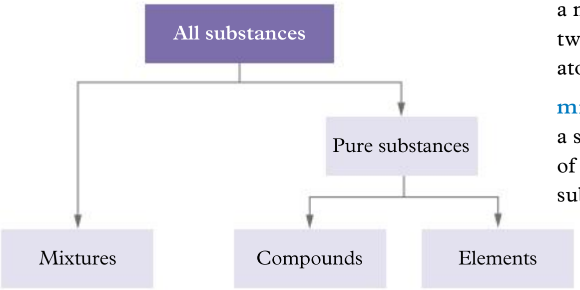

Atoms of element X
Atoms of element Y
Mixture of elements X and Y
Compound of elements X and Y

Figure 5 Mixtures are different from compounds.



molecular compound
a molecule that contains two or more different atoms bonded together

mixture
a substance made up of two or more pure substances mixed together

Figure 6 A polyethylene molecule is made up of thousands of carbon atoms joined in a chain, with hydrogen atoms attached to the carbon chain. It is a polymer.

polymer
a long-chain molecule formed by the joining of many smaller repeating molecules (monomers)

pure substance
something that contains only one type of substance (e.g. a single element or a single compound)

5.2 Check your learning

Remember and understand

1 **Identify** two elements that exist as molecules rather than single atoms.

2 **Compare** (the similarities and differences between) molecules and compounds.

3 **Contrast** (the differences between) the following terms:
  - **a** atoms and molecules
  - **b** elements and compounds
  - **c** diatomic and monatomic
  - **d** molecule, polymer and lattice.

Apply and analyse

4 **Identify** which of these diagrams show (i) a mixture of an element and a compound, (ii) a mixture of two elements, and (iii) a pure element. **Justify** your decision (by defining each term and describing how this matches the diagram).

5 Ammonia is a gas that contains molecules with the formula NH_3. **Identify** the elements that are present in ammonia and the number of each type of atom in each ammonia molecule.

Evaluate and create

6 A student claimed that 'all elements are molecules, but not all molecules are elements.' **Evaluate** this statement by:
  - > defining the terms 'molecules' and 'elements'
  - > deciding whether the first part of the claim is correct
  - > deciding whether the second part of the claim is correct.

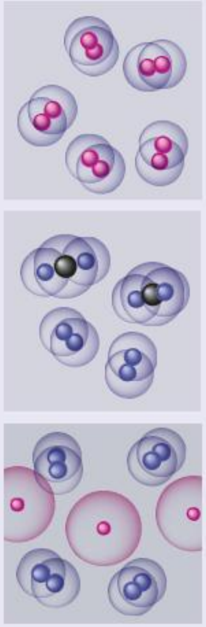


Figure 7 Compound or mixture?

5.3 Physical change is a change in shape or appearance

In this topic, you will learn that:

- a physical change occurs when the molecules remain the same but the substance has different properties.
- a change in state (solid, liquid or gas) is a physical change.
- physical changes can be reversed.

Figure 1 Ice melting to water is an example of a physical change.

lattice	a three-dimensional arrangement of particles in a regular pattern
vaporise	change state from a liquid to a gas; evaporate
vapour	gaseous form of a substance that is normally solid or liquid at room temperature (e.g. water vapour)
volatile	describes a substance that easily becomes a gas
boiling point (BP)	the temperature at which a liquid boils and becomes a gas
condense	to become a liquid, from a gas

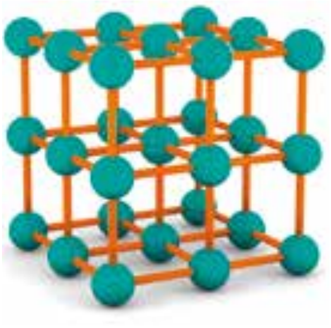


Figure 2 Particles in a solid may be arranged in a lattice.

Physical changes are reversible

Most physical changes are reversible, which means the change can be undone and the substance goes back to how it was. When you put water (H_2O) in the freezer, it turns to solid ice (H_2O). When you take the ice out of the freezer, it melts back into liquid water. In this way we observe that a physical change has taken place because the water molecules are unchanged and no new substances have been created.

Particles don't change when they change state. The molecule of water that contains two hydrogen atoms and one oxygen atom (H_2O) is exactly the same when it is a solid, a liquid or a gas. The only difference is how closely packed all the water molecules are and how much kinetic energy they have.

In ice, all the water molecules are in a regular arrangement (rows, columns and layers). A three-dimensional arrangement of particles in a regular pattern is called a **lattice**. The water molecules in ice are constantly vibrating. This ice lattice is unique when compared to all other solids. Most solids are smaller and more compact than their liquid versions. The solid ice is different because it takes up more space than the liquid water. This is because the 3D bonds between the water molecules take up more space in the solid than the liquid.

When heat energy is added, the water molecules vibrate faster. However, the molecules are still held in place in the lattice by other water molecules around them. As the ice warms up more, the water molecules gain more energy and vibrate even faster. Eventually they have so much energy that the water molecules break free of the others around them and are free to move around. The solid ice has melted to become liquid water.

Changing state

Substances can change between the three states. You are familiar with seeing water change state (when ice blocks melt), but other substances may only ever be seen in one state. Theoretically, all substances can be changed into different states if the temperature is hot (or cold) enough. Even gases, such as nitrogen, can be turned into a liquid at very low temperatures. 'Dry ice' is actually solidified carbon dioxide (CO_2).

Vaporisation and condensation

When a liquid evaporates to become a gas, we say it has evaporated or **vaporised**. A **vapour** is the gaseous form of a substance that is normally a solid or liquid at room temperature. For example, when water is turned into a gas, it is referred to as water vapour. Vapours that are smelly are often called fumes. Vapours and fumes are gases and will behave like gases.

Volatile substances, such as petrol, vaporise easily. Cooking oil does not vaporise if left at normal room temperatures. Cooking oil is not a volatile liquid.

Boiling occurs when we heat a liquid to change it into a gas. Water left in the open at normal room temperature will evaporate very slowly. If the water is heated to its **boiling point**, the water molecules will quickly gain kinetic energy and evaporate or vaporise faster.

When a gas cools down, we say it **condenses** into a liquid. The most common condensation you can observe is when your breath condenses on a cold surface. The kinetic energy of the water molecule passes to the surface as heat energy. The water molecules do not change, but they cool down, slow down and condense from a gas to a liquid.

EXPERIMENT

5.3A: Melting chocolate
Go to page **211**.

CHALLENGE

5.3B: Exploring physical changes
Go to page **212**.

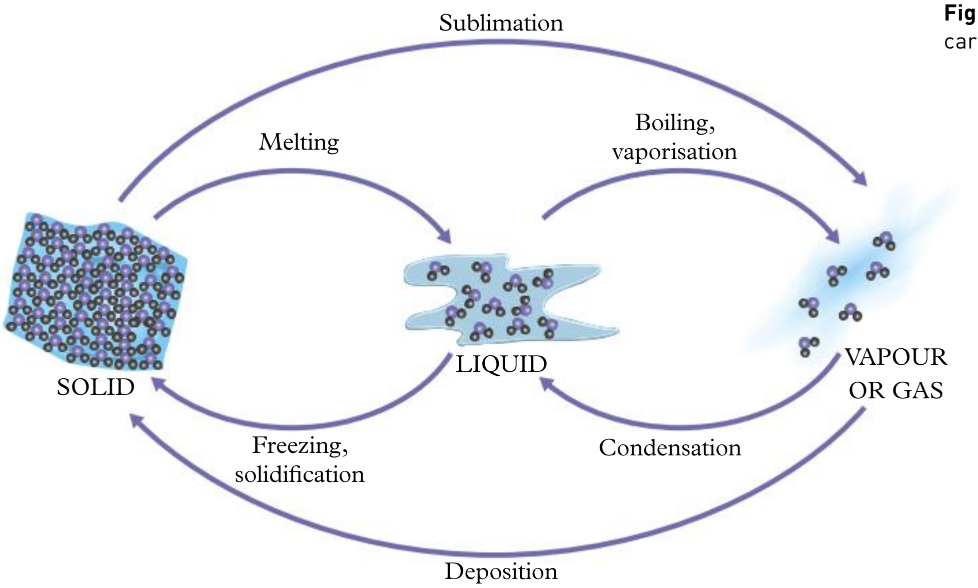


Figure 3 Changing states of water molecules. A solid contains lattice water molecules, a liquid contains a loose arrangement of water molecules and vapour or gas contains separated water molecules.

Figure 4 Dry ice is frozen carbon dioxide gas.

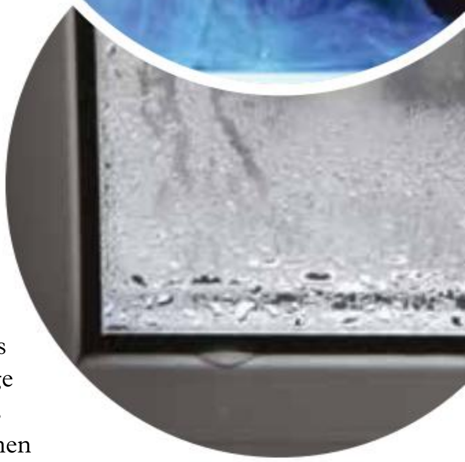


Figure 5 Water vapour in the air has condensed on this cold window.

Melting and solidification

When a solid is heated and changes state to become a liquid, we say it has **melted**. When the liquid loses heat and becomes a solid, it is called solidification. When solidification happens to water, it is sometimes called freezing. In both these examples the molecules do not change, only the amount of energy they have changes.

Sublimation

Some substances don't ever exist as liquids. They just change state from a solid to a gas or from a gas to a solid. The process of a solid becoming a gas is called **sublimation**. Dry ice (CO_2) changes directly from a solid into a gas when it warms up. Dry ice is often used to produce smoke effects on stage at concerts. However, the 'smoke' you see is not carbon dioxide, but clouds of water. When dry ice sublimes to form carbon dioxide gas, it cools the air quickly. This drop in temperature causes water vapour in the air to condense and form clouds of water.

Diamond is the hardest known substance on Earth. It also sublimes, but only at extremely high temperatures (above 3500°C).

melt
change state from solid to liquid

sublimation
a change of state from a solid directly to a gas

5.3 Check your learning

Remember and understand

1 **Describe** the meaning of the following words:

a	lattice	**b**	sublimation
c	condense	**d**	volatile.

Apply and analyse

2 **Explain** why physical changes are reversible.

3 **Explain** why shattering a block of ice is considered a physical change.

4 **Explain** why all perfumes are volatile liquids.

Evaluate and create

5 Draw a diagram with the three major states of water. **Identify** the physical changes the water goes through to form ice and water vapour.

6 A student claimed that the bubbles in boiling water were oxygen. **Evaluate** their claim (by describing the kinetic energy changes that occur in boiling water, describing the types of molecules found in the bubbles and deciding if the statement is correct).

Figure 6 Many waterfalls solidify during winter.

5.4 Chemical change produces new substances

In this topic, you will learn that:

- chemical changes can cause heat or light to be produced.
- chemical changes can cause an object to change colour.
- chemical changes can cause a new gas or solid to be formed.
- when a chemical change occurs, a new substance is formed.

Interactive 5.4
Physical and chemical changes

Chemical changes

In a chemical change, a new chemical is made. This means that the atoms have been moved around into new arrangements. In some chemical changes, the atoms in a molecule can be separated to make new chemicals. Sometimes atoms and molecules join together to make new chemical substances with larger molecules. New substances have new particles and new properties. Both the physical and chemical properties of the new substance (the product) will be different from those of the original substance (the reactant).

In every chemical reaction, one or more substances are changed into new, different substances with different physical and chemical properties. Chemical changes are usually not reversible – you cannot un-burn toast!

Whether a change is physical or chemical depends on the substances, the temperature and how you mix them.

Figure 1 Heating chocolate slowly causes it to melt – a physical change. If it is heated quickly and at a higher temperature, the chocolate will burn – a chemical change.

Physical change or chemical change?

When solid chocolate is heated gradually, it melts and changes shape; when cooled, it goes back to the solid state. It may have a different shape, but the molecules are the same. It is still chocolate. In this situation, a physical change has taken place because the chocolate is still the same substance: it is still made up of the same particles.

However, if you heat chocolate at too high a temperature, it burns. When it cools, it no longer tastes of chocolate, but of burnt chocolate. This is a chemical change, because a new substance is formed that is different from chocolate – you can tell by the taste and smell! This is why most chocolate recipes suggest heating chocolate over boiling water rather than over a hot plate, so that the chocolate does not get too hot and a chemical change does not take place.

When you bake a cake, mixing the ingredients together produces a physical change. Baking the cake involves a chemical change.

Cooking often turns food brown. This is due to the sugar in the food caramelising – turning into brown caramel. Aboriginal and Torres Strait Islander peoples used carefully controlled heat to cause a chemical change to produce a red pigment (iron oxide) for their paintings. The change forms a new substance and is not reversible. It is a chemical change.

We can usually identify a chemical change if one of the following occurs (see Figures 2 to 5).

Figure 2 A gas is produced, which we either see as bubbles or fizz.

CHALLENGE

5.4A: Making caramel
Go to page **212**.

EXPERIMENT

5.4B: Observing chemical reactions
Go to page **213**.

Figure 3 A colour change occurs that is non-reversible. Heating an iron nail to red hot is a physical change because the red colour will disappear as the nail cools down; however, if the iron in the nail reacts with air and becomes rusty, it is a chemical change.

Figure 4 Light or heat is absorbed or produced in chemical reactions. When the atoms in sodium metal and water rearrange themselves, the extra energy is released as light and heat.

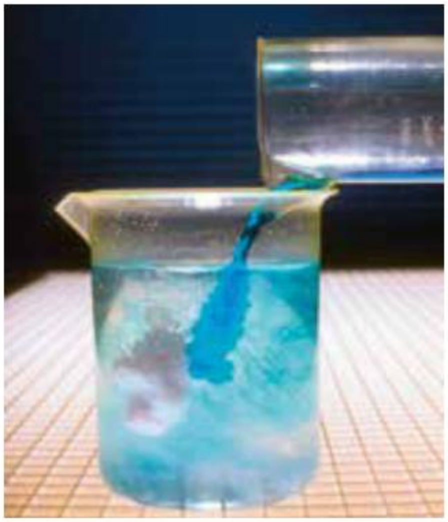


Figure 5 A precipitate forms. A precipitate is the name given when new solid particles form during a chemical change.

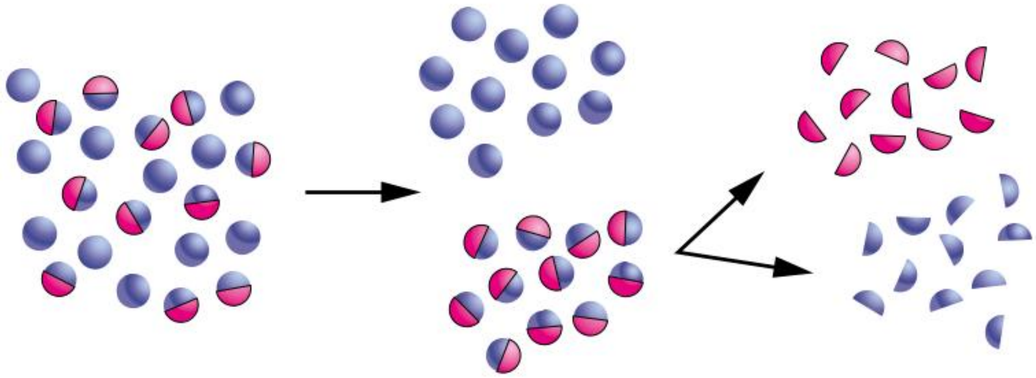


Figure 6 In a physical change, only the appearance of the substance changes because the particles have been rearranged. In a chemical change, atoms are rearranged and new chemicals are made.

Figure 7 Burning toast is a chemical reaction – it cannot be unburnt (reversed).

5.4 Check your learning

Remember and understand

1 When melted chocolate is put in the fridge, it cools quickly, producing small crystals that were not present before. This changes the taste of the chocolate. **Identify** this as a chemical or physical change.

2 **Describe** the observations that would tell you that a chemical change had occurred.

3 **Identify** the following as either a physical or a chemical change.

- **a** melting cooking chocolate into animal shapes
- **b** burning magnesium ribbon to form a white ash
- **c** boiling water and condensing the vapour
- **d** dissolving magnesium in acid to produce hydrogen gas
- **e** separating leaves from woodchips using a garden blower

4 **Identify** the key evidence that suggests that producing the reddish-brown pigment from yellow ochre is a chemical change.

Apply and analyse

5 Sugar turns brown when heated in a process called caramelisation. **Explain** why caramelisation is considered a chemical reaction.

6 **Describe** the evidence that baking a cake from egg, flour and butter is a chemical reaction.

5.5 Chemical reactions can break bonds and re-form new bonds

In this topic, you will learn that:

- in a chemical reaction, the starting molecules are called reactants.
- the products are the final molecules formed and can have new properties.
- in chemical changes or reactions in substances, the atoms in the reactants separate from each other and bond together in new combinations to form new products.

chemical reaction
a procedure that produces new chemicals; same as chemical change

reactant
a substance used at the beginning of a chemical reaction; written on the left side of a chemical equation

product
a substance obtained at the end of a chemical reaction; written on the right side of a chemical equation

Chemical reactions

A chemical change can also be described as a **chemical reaction**. The substances that you start with are called **reactants**. They react or change to produce new substances. The substances that you finish with are called **products**. They are produced in a chemical change. There may be more than one reactant and product for each chemical change.

Chemical reactions are all around us. They not only occur in factories – they take place in our homes and in our bodies. Every process in your body requires chemical changes. Cooking food changes it chemically so it is more edible and easier to digest.

Reactions in cooking

Preparing and cooking food involves many physical and chemical changes to the food. There are other similarities between chemistry and cooking – some of the techniques used in cooking, such as heating, mixing and filtering, are similar to the tasks of a chemist.

There are many chemical reactions in the kitchen. Baked vegetables and meat turn brown as the sugars are caramelised. The sugar is the reactant, and the caramel is the product. Usually, the sugar comes from the breakdown of the starch granules into starch molecules, followed by a chemical change into a sugar. Other chemical changes involve the breakdown of proteins in meat. A few vitamins may be destroyed by some cooking methods.

Some chemical changes are caused by micro-organisms. Sour milk forms when a bacterium converts milk sugar (lactose) into an acid (lactic acid). The taste of sour milk is unpalatable and the large numbers of bacteria in the milk may make you sick. Cheese is made by fungi that consume the sugars in milk and cause the protein to thicken. In making yoghurt, the bacteria act as a culture (a colony of micro-organisms) that is transferred to the new medium (milk).

Other chemicals are added to our food, including flavourings, colourings, antioxidants and preservatives. These help to improve the food's appearance and increase its shelf life. Processed foods usually show a list of these additives on the packet.

Figure 1 How would a chemist use these cooking techniques?

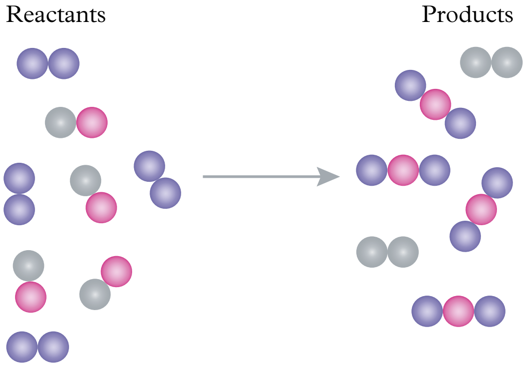


Figure 2 Reactants in a chemical reaction become products.

EXPERIMENT

5.5: Comparing reactants and products
Go to page **214**.

Aboriginal and Torres Strait Islander peoples use chemical reactions

Burning is a chemical reaction. The scientific word for burning is '**combustion**'.

Magnesium is a metal that can burn fairly easily, giving off a lot of heat and bright, white light. When a magnesium ribbon interacts with the oxygen in the air, the reactants are magnesium and oxygen. The chemical reaction takes place when we see the magnesium ribbon burn. After the ribbon has burnt, we are left with a white powder, magnesium oxide, as the product of the reaction.

Aboriginal and Torres Strait Islander peoples carefully controlled the burning of plants and wood so there were only small amounts of oxygen as a reactant. This meant that good-quality charcoal was produced (the product) that could then be used for black pigment or to improve the properties of glues for spears or axe heads.

Figure 3 The Adnymathanha people of the Flinders Ranges in South Australia used charcoal to paint the Yourambulla Rock Shelter.

New products

Many substances that we now take for granted, such as medicines, chemicals used in agriculture and construction, and plastics such as PVC and polythene, are made from chemical reactions with crude oil.

These products are hard to make in the laboratory because they require high temperatures and some specialised conditions. A substance that you can make in the laboratory is nylon – a compound consisting of long molecules (called polymers).

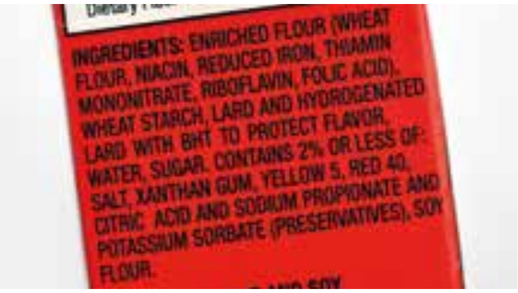


Figure 4 Some processed foods have artificial chemicals added to them.

combustion
a reaction that involves oxygen and releases light and heat energy

Chemical equations

Scientists use a shorthand technique to describe what happens to reactants and products in chemical reactions. This is called a chemical equation. The reactants are written on the left-hand side and the products are written on the right-hand side. An arrow represents the chemical change.

reactants → products

For magnesium ribbon burning in air, the chemical reaction could be represented by the following chemical word equation and chemical symbol equation:

magnesium + oxygen → magnesium oxide
(in air) (white powdered form)
$2\ Mg + 0_2 \rightarrow Mg0$

Figure 5 Nylon thread is made by mixing two solutions.

5.5 Check your learning

Remember and understand

1 Complete the following table. In the final column, include details about the substance's properties near a flame.

Substance	Formula for substance	Colour	State at room temperature	Chemical properties
Hydrogen				
Oxygen				
Water				

2 **Describe** the purpose of the arrow in a chemical equation.

3 **Explain** why it is unnecessary to write an equation for a physical change.

Apply and analyse

4 **Contrast** reactants and products.

5 **Identify** the reactant and the product in the following chemical reactions.

- a Iron ore is made into a steel ship.
- b Bread is made from flour.
- c Freezer bags made from polythene are manufactured from ethene.
- d Nitrogen fertilisers are made from nitrogen gas and hydrogen gas.
- e Carbon dioxide is produced when petrol is burnt in a car engine.

5.6 Heat can speed up a reaction

In this topic, you will learn that:

- the rate of a reaction can be sped up or slowed down.
- factors that can increase the rate of a reaction include increasing the surface area of the reactants, increasing the temperature and concentration of substances, and adding a suitable catalyst.

collision theory
a theory stating that the particles involved in a chemical reaction must collide in order to react

concentration
the number of active molecules in a set volume of solution

The effect of temperature

For substances to react, their particles must collide with each other. This is known as the **collision theory**. In the collision theory, the more collisions that happen between the particles, the more likely it is that they will react.

One way to increase the number of collisions between the particles is to increase the temperature. When heat energy is added to the substance, the particles gain kinetic energy and therefore move more quickly. To slow down a reaction, the temperature can be reduced so that the particles have less kinetic energy and have less chance of colliding.

The effect of concentration

The number of particles trapped in a small area – the **concentration** – also has an effect. More concentrated substances will react more easily, again due to the collision theory. A more concentrated substance has more particles available to collide with particles from another substance. For instance, to increase the rate of a reaction between a solid substance and one in solution, increasing the concentration of the solution will mean that there are more particles in the solution to collide with the particles in the solid.

The effect of surface area

The surface area of reactant pieces affects the rate of a reaction. When a solid reactant is cut into smaller pieces, it will react faster. This is because the smaller reactant pieces have a larger total surface area, which means that the reactant particles have a greater chance of interacting with each other.

Figure 1 An increase in temperature causes reactant particles to move faster.

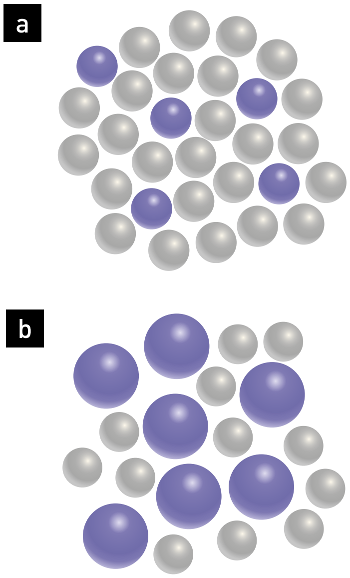


Figure 2 a More reactants can interact or touch each other when the reactant pieces are small. **b** Large reactant pieces have less total surface area to make contact with other reactants.

EXPERIMENT

5.6A: Effect of particle size on reaction rates
Go to page **215**.

EXPERIMENT

5.6B: Speeding up reactions with enzymes
Go to page **216**.

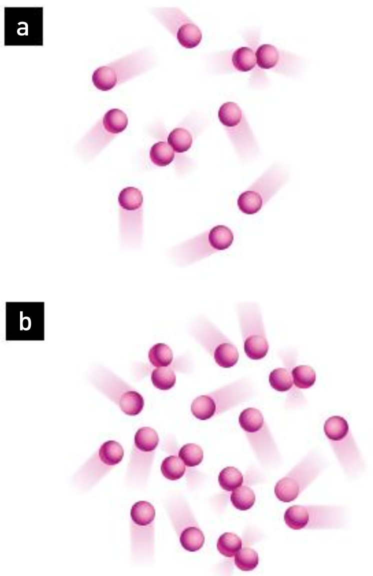


Figure 3 a At low concentrations there are few collisions between particles. **b** At high concentrations, the number of collisions between particles is increased.

The effect of catalysts

Adding another substance or material may also affect the rate of the chemical reaction. Substances that increase the rate of a reaction without becoming used up by it are known as **catalysts**.

Enzymes are types of catalysts that help speed up reactions in living things. We have many enzymes in our bodies that help to speed up chemical reactions. For example, enzymes found in the digestive system help break down food. Enzymes are very 'fussy' and only work with one type of reactant and so will only catalyse one reaction each. They act like landing strips for reactants, allowing the chemicals to collide with each other more easily.

Enzymes are responsible for the ripening of fruit. When a piece of fruit is cut and left exposed to the air, enzymes help the oxygen react with the fruit and make it turn brown. This enzyme can be blocked by adding vitamin C.

catalyst
a substance that increases the rate of a chemical reaction without undergoing any permanent chemical change

enzyme
a chemical that helps make chemical reactions happen; a type of catalyst

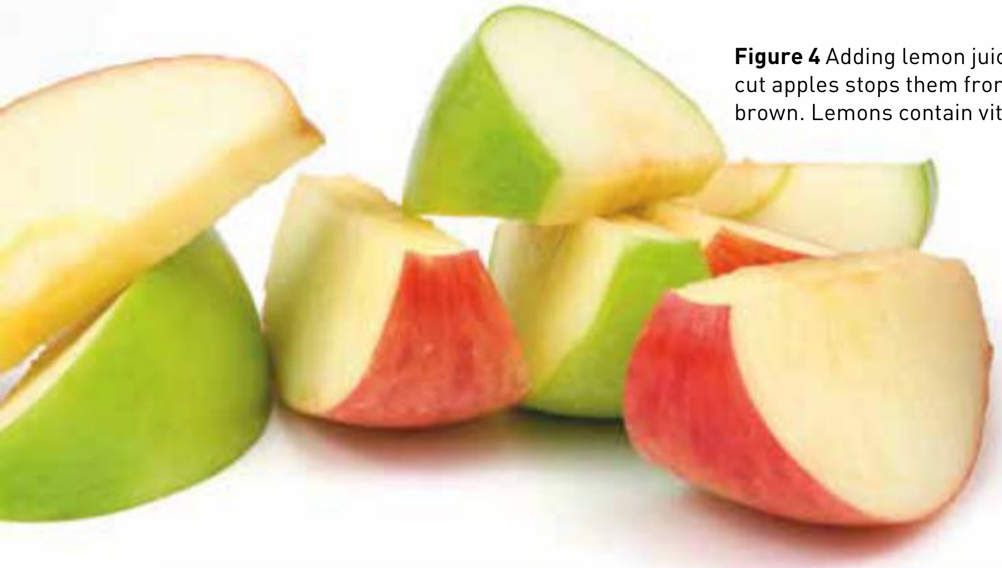


Figure 4 Adding lemon juice to cut apples stops them from going brown. Lemons contain vitamin C.

Figure 5 Why does roasting a marshmallow make it go brown?

5.6 Check your learning

Remember and understand

1 **Describe** how the particle model of matter helps to explain the rate of reactions.

2 **Explain** the collision theory in your own words.

3 **Describe** how the surface area of a solid reactant affects the rate of a chemical reaction.

4 **Describe** the effect enzymes have on the rate of a reaction.

5 **Describe** what happens to the number of particles when you increase the concentration of a substance.

6 **Explain** how increasing the concentration of reactants increases the rate of a reaction.

Apply and analyse

7 **Explain** why increasing the rate of a reaction does not change the total amount of product produced.

//SCIENCE AS
A HUMAN ENDEAVOUR//

5.7

Many substances exist because of the work of scientists

It is easy to forget just how much we rely on manufactured products in our lives. Increasingly, many substances and materials are processed (i.e. changed) or manufactured before they are used. These substances, such as medicines, electronic components, composite materials in aircraft and polymers, only exist because of the work of scientists changing them from their original state to one that you can use.

Pharmaceuticals

Pharmacies (also called 'chemist shops') are where medicines are prepared and dispensed. A pharmacist (also called a 'chemist') has studied chemistry, but has specialised in the study of medicines and their effect on the body (called 'pharmacology').

Figure 1 Pharmacists are chemists with a specialisation.

Figure 2 Many everyday items are the result of carefully considered chemistry.

Figure 3 All these products come from petroleum.

Oil refinery

Petroleum, or crude oil, is an important product in our society. Oil is pumped from the ground and is carried in pipelines or tankers to refineries, where it is separated into its many different components. The crude oil mixture is converted into high-value products, such as petrol, diesel, vitamins, medicines, cosmetics, food additives, rope, rubber, paint, putty and ink, as well as a very large number of different plastics. 'Plastic' is the common name for all the different polymers used in construction, clothes, shoes, furniture, surfboards, phone cases and much, much more.

EXPERIMENT

5.7: Making casein glue
Go to page **217**.

Glues and adhesives

Glue was used in ancient Babylon 3500 years ago when King Nebuchadnezzar used bitumen (also called 'asphalt') to hold building stones together. Later, plant gums, egg white and animal products (such as gelatine) were used for gluing paper and wood. The paints used by the old masters were made using egg white, which helped to hold the parts of the paint mixture together.

Figure 4 Older paints contained egg white to help hold the paint together.

In the First World War, aircraft were made of wood. The wood was glued with casein glue (casein is a protein in milk) and albumin (a protein in egg white).

Nowadays, many synthetic glues are used. Once, shoes were made of layers of leather nailed and sewn together; now these layers are mostly glued. Glue is used to hold many things together, including the chips in chipboard and the layers in MDF board, and plywood in a lot of furniture. Even the brake linings in cars are glued (bonded).

Figure 5
A glue is any substance that sticks things together.

Dyes

Before the use of dyes, all clothes had the same colour – the off-white colour of natural fibres, such as raw cotton, silk and wool.

The first dye was obtained from murex whelk shells, a type of sea snail. It took 12,000 snails to make just 1.4 g of dye, which is enough to colour the edge of one Roman emperor's toga. For this reason, purple clothes were traditionally reserved for high-ranking officials. The whelk almost became extinct as a result of being hunted for its dye.

The soldiers in the British Army used to be known as 'redcoats' because their uniform included a red coat, which used to be dyed red using the liquid extracted from scale insects. This red dye, called carmine, is still available today in supermarkets, but it is now made synthetically.

The first synthetic (or artificial) dye was discovered accidentally by William Perkin in 1856. He named his dye after its colour, mauve. Soon, many other coloured dyes had been discovered and were being manufactured.

Computer printers use dyes when they print photographs. Modern inks do not fade, so modern photographs last longer than paintings made many years ago.

Figure 6 Dyes, like the colour in this British soldier's coat, originally came from living organisms. Today they are mostly synthetic.

5.7 Develop your abilities

Using design thinking to solve problems

Making casein glue requires you to use science inquiry skills and design thinking to produce the glue.

Not all glue needs to be super strong. Dr Spencer Silver was a chemist who researched glues for the 3M company. His job was to make new, stronger glues. Unfortunately, one of his glues was so strong it curled up into small spheres. Because it was stuck to itself, the glue just peeled off everything else. Another scientist who worked at 3M, Art Fry, used to sing with his church choir each week. Each week he would become frustrated that the bits of paper that marked the songs he was going to sing would fall out of his book. When Art and Spencer were talking one day, they came up with the idea of small bits of paper that could be glued to the pages of a book and then peeled off when they were finished. They tried many different chemical reactions until they found one that produced the right product. Post-it notes were invented.

The cycle of design thinking involves empathy (understanding someone's problem from their point of view), ideation (thinking of possible solutions to a problem), building and testing the prototype and communicating the results. **Identify** each of these stages in the invention of the Post-it notes.

//SCIENCE AS
A HUMAN ENDEAVOUR//

5.8 Physical and chemical changes are used to recycle household waste

Understanding the difference between physical and chemical reactions can help us to understand which objects can be recycled. Objects that can undergo physical reactions can be easily recycled because the reactions are reversible and new shapes can be formed. Chemical reactions can be used to create new materials that can be used again.

Types of plastic

As you discovered in Topic 5.7, plastics are made from a chemical reaction with crude oil. This is hard to recycle and, as most plastic products are only designed to be used for one year, they often end up in landfill. Recycling the chemicals in the plastic is often cheaper than the oil needed to create new products.

All recycled plastic belongs in seven groups (see Figures 2 to 8).

Physical recycling of plastics

Mechanical recycling, also called physical recycling, is broken into several steps.

1. Cutting the large pieces of plastic using shears or saws.
2. Shredding the plastic into small flakes.
3. Separating the contaminants in cyclone (centrifuge) separators.
4. Floating off the plastics according to their density.
5. Extruding the plastic by heating it to a melting state and forcing it into long strands.
6. Cooling the strands and cutting it into small pellets so that it can be reused for new products.

Chemical recycling of plastics

Chemical recycling involves creating a chemical reaction that causes the long polymer molecules that make up the plastic to break into smaller molecules called monomers. This requires a lot of energy because it is trying to reverse the initial chemical change that created the plastic. As the initial reactants (crude oil) become more expensive, the chemical recycling of plastics will become a more attractive option.

Figure 1 Water bottles use plastic.

Figure 2 Polyethylene terephthalate (PET or PETE) is the plastic used to make soft drink bottles and oven-ready meal trays.

Figure 3 High-density polyethylene (HDPE) is used to make milk and juice bottles, some washing-up bottles, toys and grocery bags.

Figure 4 Polyvinyl chloride (PVC) is used to make clear food packaging, shampoo and medication bottles, and food trays.

Recycling of metals

Metals such as iron can be easily recycled using physical reactions. This means the metal can be heated until it melts, and then reshaped into its new form. One of the problems with recycling metals, such as iron, is that they easily rust. You will have seen rust on cars, food tins, tools, fences, roofs and bridges.

Rust is the most common type of corrosion. **Corrosion** is a chemical reaction between a substance and its environment. Rusting refers to the corrosion of iron and steel objects when they are exposed to air. These materials tend to rust very easily and, once the reaction starts, it is difficult to slow or stop. The rust is a reddish-brown compound called iron oxide that forms from the reaction of iron with oxygen, as shown in the word equation below.

iron + oxygen → iron oxide

corrosion
the gradual destruction of materials by a chemical reaction with their environment

Figure 9 A can undergoes a physical change when it is compacted.

Figure 5 Low-density polyethylene (LDPE) is used to make grocery bags, bin liners, bread bags and frozen food bags.

Figure 6 Polypropylene (PP) is used to make microwave meal trays, sauce bottles, yoghurt containers and medicine bottles.

Figure 7 Polystyrene (PS) is used to make foam meat or fish trays, coffee cups, plastic cutlery and sandwich boxes.

Figure 8 Group 7 contains all other plastics, including nylon and fibreglass, that cannot be recycled.

5.8 Develop your abilities

Evaluating recycling approaches

There are many different ways the plastics and other forms of rubbish produced in your household can be recycled. These include:

- burning plastic to produce heat for electricity
- separating the seven types of plastic into different bins so they can be recycled separately
- collecting food stuffs in a separate bin so they can be composted
- recycling old jeans into new materials
- recycling plastic bags into new carpeting, floor mats and tiles
- breaking down the toxic chemicals in batteries to be recycled
- allowing metals to rust completely.

Select one of these approaches to recycling and research if it occurs in your area.

1 For your selected recycling method, **identify** how much it financially costs to recycle your product, if any toxic by-products are produced (cost) and how useful the product would be to your community (benefit).

2 **Compare** your chosen recycling method to another approach researched by someone else in your class.

3 **Identify** which approach is the most important by comparing the pros and cons of each.

REVIEW 5

Multiple choice questions

1 **Identify** which of the following describes a chemical change.
- A breaking glass
- B burning toast
- C melting ice
- D mixing sand and water

2 In a chemical reaction, the new substance that is produced is called:
- A the chemical
- B the result
- C the product
- D the reactant.

3 Which of the following describes how a physical change is different from a chemical change?
- A A physical change refers to rusting or cooking processes.
- B A physical change requires heat.
- C A physical change is permanent.
- D A physical change is reversible.

Short answer questions

Remember and understand

4 Use the particle model to **explain**:
- a melting
- b freezing
- c sublimation
- d condensation.

5 **Define** a reactant (in a chemical reaction).

6 **Describe** the changes that might be observed during a chemical change.

7 **Contrast** a physical change and a chemical change.

8 Using your knowledge of particles, **explain** why most physical changes can be reversed.

9 **Describe** four ways to speed up a chemical reaction. Use the particle model to explain why each method works.

10 **Describe** three uses of chemicals in the home.

11 **Explain** why nylon is described as a synthetic material.

12 **Identify** an object that is made from PVC.

13 **Contrast** elements and compounds.

14 **Contrast** a group or a period in the periodic table.

15 Draw a picture of a reactant and a product that represents a chemical change.

Apply and analyse

16 **Explain** why chemists would never write a chemical equation for the melting of chocolate.

Figure 1 Chocolate can be easily burnt.

17 In one experiment, you observed the reaction between copper sulfate solution and iron to make copper and iron sulfate solution.
- a Complete the following table to summarise the changes observed in this reaction.

Name of reactants	Description	Name of products	Description

- b Use the information in the table to **explain** why this is an example of a chemical change.

18 Dyes can be synthetic or natural in origin.
- a **Describe** one advantage and one disadvantage of using natural dyes.
- b **Describe** one advantage and one disadvantage of using synthetic dyes.

Figure 2 Dyes involve soaking materials in a solution.

19 The following are descriptions of interactions that occur around us in our daily lives. **Describe** what the products of these interactions might be and **explain** whether you think the changes described are useful or harmful.
- a A bike is left out in the rain so that parts of the bike that are made of steel are in contact with water for a few hours.
- b A barbecue fuelled by propane gas is turned on.
- c A hairdresser applies bleach to someone's hair.

Evaluate

20 Some of the chemical changes that occur with food are described as biochemical reactions. **Define** the term ‘biochemical’ and use this to **evaluate** the accuracy of the statement.

21 Think about your morning routine from when you wake up to when you arrive at school. **Describe** how the things you complete in your routine would be different if you were only allowed to use all-natural materials. You might want to think about brushing your teeth, wearing your school uniform, eating breakfast, your school bag and travelling.

Figure 3 Can everything you use be replaced with all-natural materials?

22 Substances can change when they interact with each other. In each of the following situations, a change is described. For each change, **describe** the interactions that have caused the change to occur. The first one has been done for you.

- **a** Glue makes a bond between two pieces of wood.
  Possible answer: The glue interacts with the oxygen in the air, which causes it to set hard, which joins the two pieces of wood together.
- **b** Sugar turns into caramel.
- **c** Charcoal burns in air to form the gas carbon dioxide.
- **d** Starch is digested in our stomach to form simple sugars, such as glucose.
- **e** A loaf of bread rises in an oven as carbon dioxide gas is produced.

Social and ethical thinking

23 An environmental action group wants to ban the use of chemicals in your school.

Either:

- **a** Write a letter to your school principal explaining why you think this would be a good idea.

Or:

- **b** Write a letter to the leader of the environmental group explaining why you think this is a bad idea.

Critical and creative thinking

24 The use of chemistry to produce new materials has affected people’s lives in a range of ways.

- **a** **Describe** how new materials have changed the type of clothes that people wear.
- **b** **Describe** how new materials have changed the type of food that people eat.

25 **Describe** a chemical change that may be harmful to the environment if it is allowed to occur in an uncontrolled way. **Create** a poster that describe the danger and offers a solution.

Research

26 Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

» Magic or chemistry?

Magicians use a range of tricks to deceive the audience into thinking magic is real. Some of these tricks use chemical reactions. What sort of chemical reactions could be used by magicians? What sort of physical changes could be used in tricks performed by magicians? How does the ‘magic’ happen?

» Explosives

The history of the development of explosives is fascinating. Who discovered them? When were explosives first used and how do they work? What are the main chemicals used and what types are there? What part did Alfred Nobel play?

» Respiration

Respiration is a chemical process that occurs in our body and is essential for our survival. What are the reactants used in respiration? What are the products? Where in our bodies does respiration occur? Why is respiration such an important process?

» Barbecue fuels

Most home barbecues burn liquefied petroleum gas (LPG) as the fuel. This is the gas that can be bought in cylinders at hardware and camping stores. What chemicals are present in LPG? What are the advantages of gas barbecues over solid fuel barbecues? What safety precautions must be followed when storing LPG cylinders?

Reflect

The table below outlines a list of things you should be able to do by the end of Chapter 5 ‘Physical and chemical change’. Once you’ve completed the chapter, use the table to reflect on your ability to complete each task.

	I can do this.	I cannot do this yet.
Define and describe the key features of the periodic table including periods, groups, elements, monatomic gases and diatomic gases. Relate the atomic number and mass number of an element to its subatomic particles.	☐	☐ Go back to Topic 5.1 ‘Atoms and elements make up matter’ Page 92
Define molecule, compound, bonded, molecular element, molecular compound and polymers, and provide an example of each. Explain the difference between an element, molecule, compound and mixture.	☐	☐ Go back to Topic 5.2 ‘Atoms bond together to make molecules and compounds’ Page 94
Define vaporise, vapour, fumes, volatile, boiling, condense, melt and sublimation. Describe the processes involved in each change of state. Explain the physical differences between a physical and a chemical change.	☐	☐ Go back to Topic 5.3 ‘Physical change is a change in shape or appearance’ Page 96
Provide examples of chemical and physical changes. Identify the features of a chemical change.	☐	☐ Go back to Topic 5.4 ‘Chemical change produces new substances’ Page 98
Define chemical reaction, reactants and products. Describe the purpose of chemical equations.	☐	☐ Go back to Topic 5.5 ‘Chemical reactions can break bonds and re-form new bonds’ Page 100
Define collision theory, concentration, catalyst and enzyme. Compare and contrast enzymes and catalysts. Explain factors that increase the rate of a reaction.	☐	☐ Go back to Topic 5.6 ‘Heat can speed up a reaction’ Page 102
Describe how chemical reactions are used in everyday life. Provide examples of everyday experiments.	☐	☐ Go back to Topic 5.7 ‘Science as a human endeavour: Many substances exist because of the work of scientists’ Page 104
Classify the processes involved in recycling plastic as physical or chemical changes. Explain the benefits of recycling.	☐	☐ Go back to Topic 5.8 ‘Science as a human endeavour: Physical and chemical changes are used to recycle household waste’ Page 106

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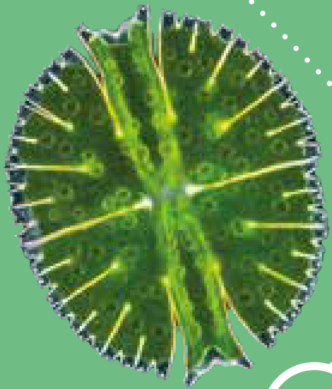
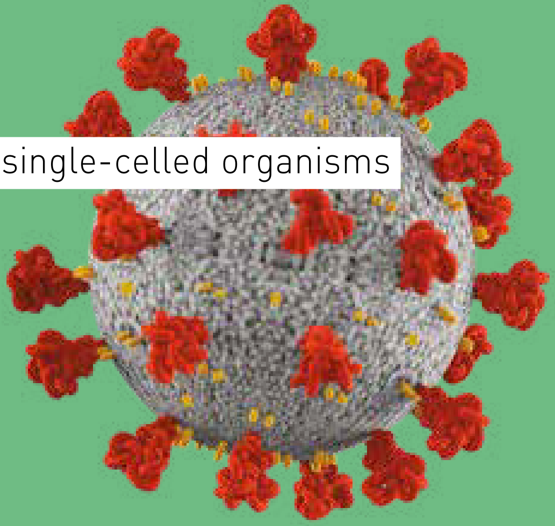
CHAPTER 6

CELLS

What is the smallest living thing?





What if?

Building blocks

What you need:

Building blocks (e.g. Lego blocks)

What to do:

1 Use the blocks to make a cube.
2 Rearrange the blocks to make a pyramid shape.
3 Rearrange the blocks a third time to make a rough circle.

What if?

- What if you wanted to make your shapes bigger?
- What if you just had one large block? How many shapes could you make?
- What if you had different shaped blocks? How many shapes could you make?

6.1 All living things are made up of cells

In this topic, you will learn that:

- microscopes allow scientists to see the building blocks of life (cells).
- cell theory states that: all living things are made up of cells; cells are the basic unit of life and structure; all living cells are created from existing cells.

Video 6.1
All living things are made up of cells

cell	(in biology) the building block of living things
microbiology	the science involving the study of microscopic organisms

Scientists have not always known that living things are made up of cells. It was the invention of the microscope in the mid-seventeenth century that allowed us to see the building blocks of life – the tiny units that form every living thing. Microscopes showed that each and every living thing is made up of **cells**.

Discovering cells

When Robert Hooke published his book *Micrographia* in 1665 it became a bestseller. Hooke had made one of the first microscopes. With it, he observed many types of living things and made accurate drawings of what he saw.

Figure 1 Robert Hooke's drawing of cork

Hooke's most famous achievement was his diagram of very thin slices of cork (Figure 1). He was surprised to see that, under the microscope, the cork looked like a piece of honeycomb with 'holes' and 'honeycomb'. He called the small structures 'cells' because they reminded him of the small rooms in a monastery, which were also called cells. Hooke had discovered the first plant cells.

Although some called *Micrographia* 'the most ingenious book ever', others ridiculed Hooke for spending so much time and money on 'trifling pursuits'. Thankfully for us, and for the whole science of **microbiology**, Hooke ignored the name-calling and kept experimenting with microscopes.

It was because of Hooke's contribution to microbiology that other scientists went on to develop a further understanding of cells.

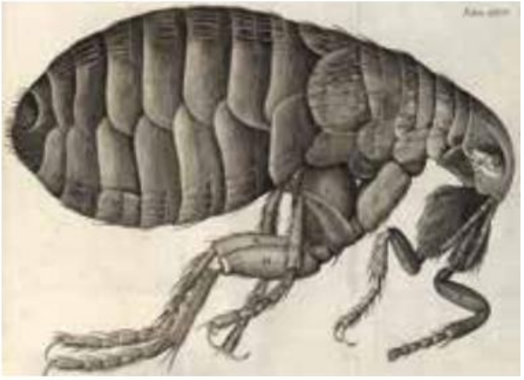


Figure 2 Robert Hooke's detailed drawing of a flea

Cell theory

Cell theory describes the properties of cells and their role in living things. It was first proposed in 1839 by two German biologists, Theodor Schwann and Matthias Schleiden. In 1858, Rudolf Virchow concluded the final part of the classic cell theory. The combined cell theory included the following principles:

> All organisms are composed of one or more cells.

> Cells are the basic unit of life and structure.

> New cells are created from existing cells.

Any living thing that has more than one cell is referred to as **multicellular**. There are many living things, such as bacteria, that consist of only one cell. These are called **single-celled** or **unicellular** organisms. **Micro-organisms**,

cell theory	theory describing the properties that all cells have in common
multicellular	an organism that has two or more cells
single-celled	an organism that consists of one cell
unicellular	living things consisting of only one cell (e.g. bacteria)
micro-organism	a microscopic organism

SKILLS LAB

6.1: Drawing cells
Go to page **218**.

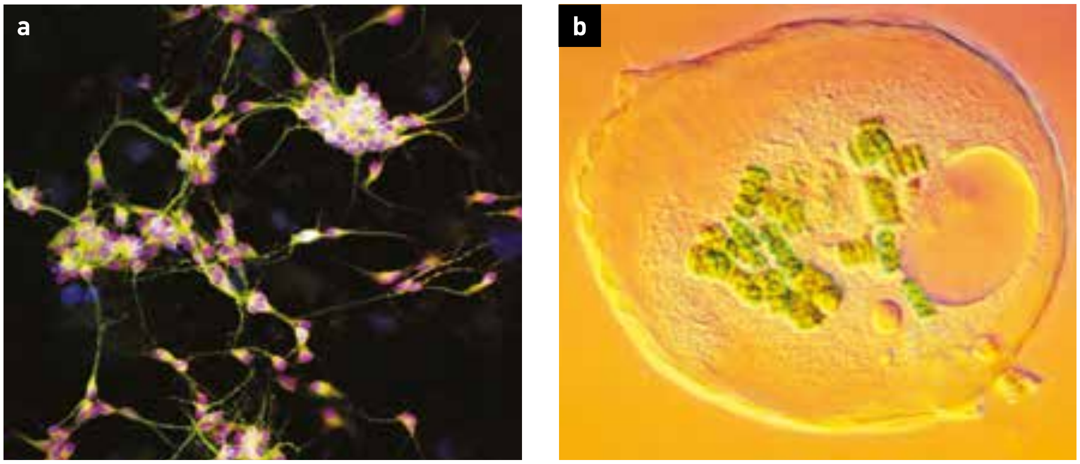


Figure 3 a Human nerve cells are part of multicellular humans, but **b** the amoeba is a unicellular organism.

microbes
living things that can only be seen with the use of a microscope; a micro-organism

cell membrane
the barrier around a cell that controls the entry and exit of substances into and out of a cell

which are also often referred to as **microbes**, are organisms that can only be seen under the microscope – they can be single-celled or multicellular.

Why are cells so small?

The outside surface of a cell is called the **cell membrane**. It controls what can move in (nutrients) or out (waste) of the cell.

Large cells have more difficulty staying alive than small cells. Large cells need to move nutrients a long way to reach the centre of the cell. Small cells do not need to make the nutrients travel as far and this makes it easier for all parts of the small cells to stay healthy and alive.

The total space inside the cell is referred to as the cell's volume while the size of the membrane is called the surface area. As a cell increases in size, both its volume and its surface area increase. The problem is, the volume increases much more than the surface area. Eventually the volume becomes so big that it is difficult for nutrients to get into the centre of the cell and for wastes to get out. We compare the relationship between the amount of surface area and the volume of a cell through a fraction – the **surface area to volume ratio**. Small cells have a large surface area compared to their volume (a large surface area to volume ratio) and are therefore better able to survive. This explains why single-celled organisms are so small. A single cell must do all the same things that a larger organism does.

The cell membrane is particularly important because it provides a barrier between the inside of the cell and the external environment. All the nutrients needed to keep the cells alive, and the waste products made by the cell, are transported across the cell membrane. It is essential that the cell membrane provides a large surface area for the transport of so many molecules into and out of the cell.

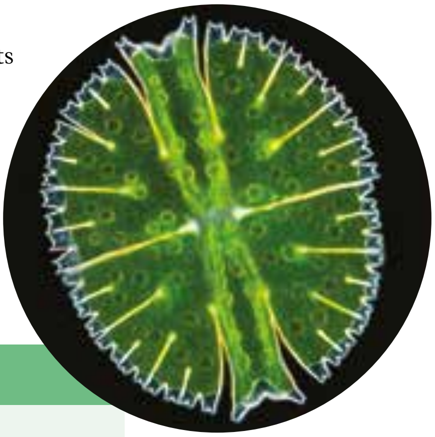


Figure 4 The irregular shape of this unicellular organism (called a desmid) maximises the surface area to volume ratio.

6.1 Check your learning

Remember and understand

1 **Identify** the person who invented the first microscope.

2 **Describe** why cells are called 'cells'.

3 **Define** the term 'multicellular'.

4 **Name** five multicellular organisms.

5 **Identify** three things that all unicellular organisms have in common.

6 **Describe** the three principles of cell theory.

Apply and analyse

7 The common house dust mite is a micro-organism. **Explain** whether you would be able to see this animal without a microscope. **Justify** your answer (by defining the term 'micro-organism' and linking the definition to the need of a microscope).

8 **Explain** whether a cell with a bigger surface area to volume ratio would be able to meet its requirements for nutrients more effectively.

9 **Explain** why unicellular organisms are always very small.

surface area to volume ratio
the relationship between the area around the outside of a cell and its volume, as a fraction

6.2 Microscopes are used to study cells

In this topic, you will learn that:

- a microscope is an instrument that uses lenses to magnify the size of objects.
- the science of investigating small objects using a microscope is called microscopy.

Video 6.2
Microscopes are used to study cells

microscope	an instrument with lenses that is used for viewing very small objects
electron microscope	a microscope that uses electrons (tiny negatively charged particles) to create images
microscopy	the study of living things that can only be seen with the use of a microscope
objective lens	lens in the column of a compound light microscope
stain	substance, such as iodine, used to make cells more visible under a microscope
stereomicroscope	a microscope with two eyepieces that uses low magnification
compound light microscope	a microscope with two or more lenses
eyepiece	where the eyes are placed when using a microscope
monocular	using one eye; a type of microscope
binocular	using two eyes; a type of microscope

Types of microscopes

As a science student, you will probably use a light **microscope** in your laboratory. You may also work with images produced by different types of microscopes, such as light microscopes and **electron microscopes**. The study of small objects using a microscope is called **microscopy**.

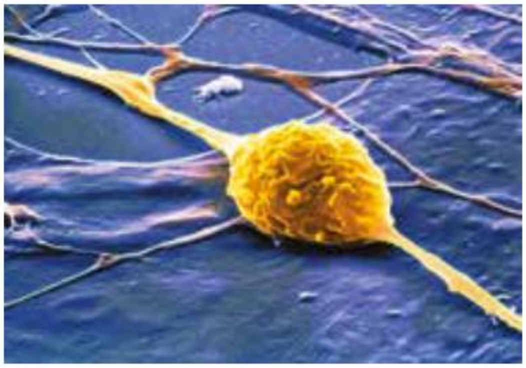


Figure 1 Image of a nerve cell under a scanning electron microscope (SEM)

Light microscopes

There are two common types of light microscope – the **stereomicroscope** and the **compound light microscope**. The stereomicroscope is used for viewing larger objects, such as insects. It can magnify up to 200 times and shows a three-dimensional view.

The compound light microscope is used to look through thin slices of specimens. It can magnify up to 1500 times. Its view is two-dimensional. The specimen must be thin enough to allow light to pass through it.

The stereomicroscope has two **eyepieces** to look through, whereas the compound light microscope can have one or two eyepieces. The word **monocular** is used to describe a microscope with one eyepiece (mono = one).

Microscopes with two lenses are called **binocular** (bi = two). The compound light microscope uses two lenses (one in the eyepiece and one further down the column, called the **objective lens**). Most cells are clear or transparent so a **stain**, such as iodine, can be used to help make them more visible.

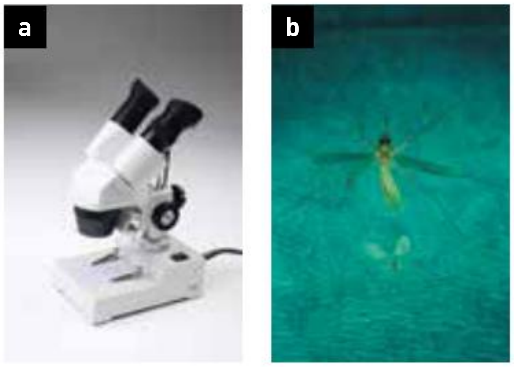


Figure 2 a A stereomicroscope **b** An insect, as seen under a stereomicroscope

Electron microscopes

An electron microscope uses electrons (tiny negatively charged particles) to create images. The first electron microscope, the transmission electron microscope (TEM), was invented in 1933 to help study the structure of metals. The scanning electron microscope (SEM), developed later, uses a beam of electrons to scan across the surface of a specimen. A computer is used to recreate the image, showing details of its surface (see Figure 1).

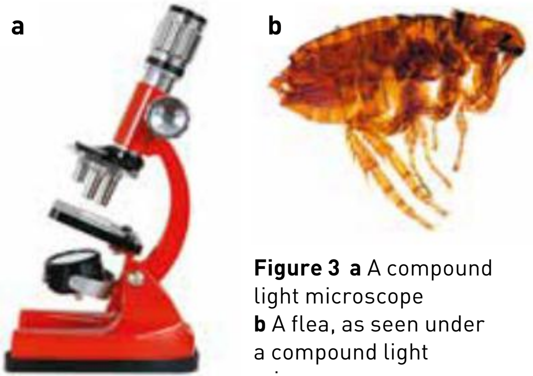


Figure 3 a A compound light microscope
b A flea, as seen under a compound light microscope

SKILLS LAB
6.2: Getting to know your microscope
Go to page **219**.

Electron microscopes can magnify up to a million times. Using this technology, many more details of the cell can be seen and understood.

Getting to know your compound light microscope

Figure 4 shows the parts of a monocular compound light microscope. Microscopes are fragile instruments that must be treated with care.

- Always use two hands to carry a microscope – one hand around the main part of the instrument and the other underneath it.
- Some microscopes have a built-in lamp. Others have separate lamps that need to be set up so they shine onto the mirror. Adjust the mirror to project the light through the stage onto the specimen. Do not allow sunlight to shine directly up the column.
- Place the slide on the stage then select the objective lens with the lowest magnification.
- Look from the side and adjust the coarse focus knob so that the objective lens is *just above – and not touching* – the slide. Check which way you must turn the knob to move the objective lens away from the slide.
- Use the coarse focus knob to bring the specimen into view. Use the fine focus knob to help you see it more clearly.
- If you want a higher magnification, rotate the objective lens to a higher magnification.
- Draw what you see (as a record) using a sharp grey pencil.
- Work out the total magnification.
- Write the magnification next to your sketch.
- Label and date the sketch.

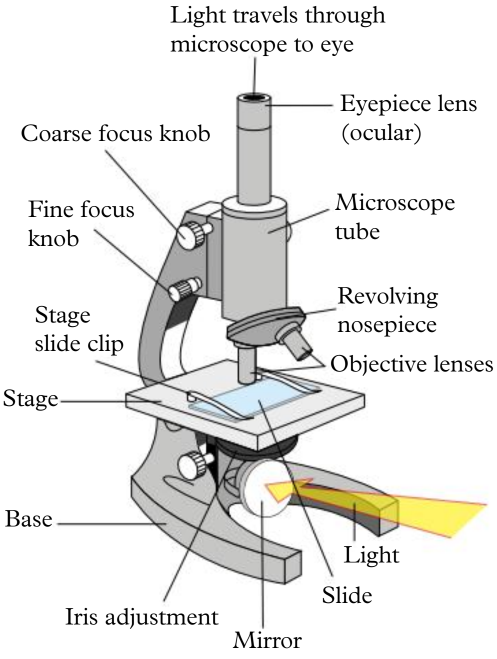


Figure 4 Parts of a compound light microscope

Magnification calculations

Using different combinations of lenses means you can magnify your object by different amounts. To calculate the total magnification of a compound light microscope, multiply the magnification of the eyepiece lens by the magnification of the objective lens (see Worked example 6.2 and Table 1). These figures are marked on each lens.

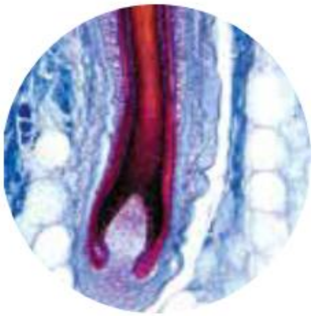


Figure 5 A stained human hair root seen under a microscope.

Worked example 6.2 Calculating magnification

Calculate the final magnification of a cell that can be seen when using a ×4 objective lens and a ×10 eyepiece lens.

Solution

Magnification = eyepiece lens magnification × objective lens magnification
= 10 × 4
= 40

The cell was magnified 40 times larger than normal.

Table 1 The total magnification of a microscope can be determined by multiplying the magnifications of the eyepiece and the objective lens.

Eyepiece magnification	Objective lens magnification	Total magnification
× 5	× 10	× 50
× 10	× 20	× 200

6.2 Check your learning

Remember and understand

1 **Identify** the type (or types) of microscopes in your science laboratory.
2 **Explain** why you should look from the side when first adjusting the coarse focus knob.
3 **Explain** why very thin samples should be used under a light microscope.
4 **Define** the term ‘microscopy’.

Apply and analyse

5 **Explain** why it is important to label and date your specimen drawings.
6 Complete the following magnification table for a compound light microscope by **calculating** the missing values.

Eyepiece magnification	Objective lens magnification	Total magnification
× 5		× 100
	× 20	× 300
× 10	× 50	

6.3

Plant and animal cells have organelles

In this topic, you will learn that:

- a cell is the smallest basic unit of life.
- all cells have a membrane, cytoplasm and genetic material (DNA).
- all plant and animal cells are made up of smaller organelles.

Interactive 6.3A
Parts of a cell
Interactive 6.3B
Plant cells

cytoplasm
the 'jelly-like' fluid inside the cell membrane that contains dissolved nutrients, waste products and organelles

DNA (deoxyribonucleic acid)
a molecule that contains all the instructions for every job performed by the cell; this information can be passed from one generation to the next

nucleus
control centre of a cell that contains all the genetic material (DNA) for that cell

Cell structures

All cells, regardless of which type of organism they are found in, share the same basic structure. This basic structure includes three key features.

- Cell membrane – this acts like the 'skin' of a cell, forming a barrier around the cell. It controls the entry and exit of things into and out of the cell.
- **Cytoplasm** – this is the jelly-like fluid and structures inside the cell membrane. It helps provide structure to the cell and contains many dissolved nutrients and waste products.
- **DNA (deoxyribonucleic acid)** – this contains the instructions for every job your cells need to do and is passed from one generation to the next. The code for half your DNA came from your mother, and the other half came from your father. The same complete set of DNA is found in every one of your cells. Plant and animal cells keep their DNA surrounded by a membrane to form a **nucleus** (the control centre of the cell).

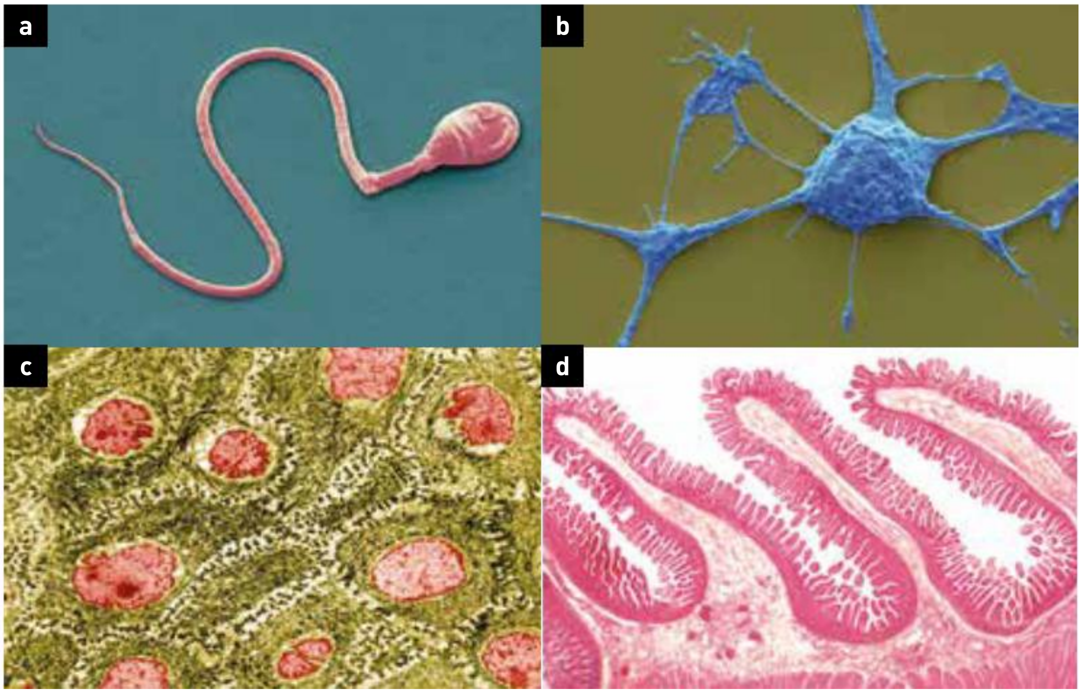


Figure 1 Cells can be different shapes and sizes: **a** sperm cell, **b** nerve cell, **c** skin cell and **d** intestinal cell.

CHALLENGE

6.3A: Comparing the size of cells and their parts
Go to page **220**.

AN ANIMAL CELL

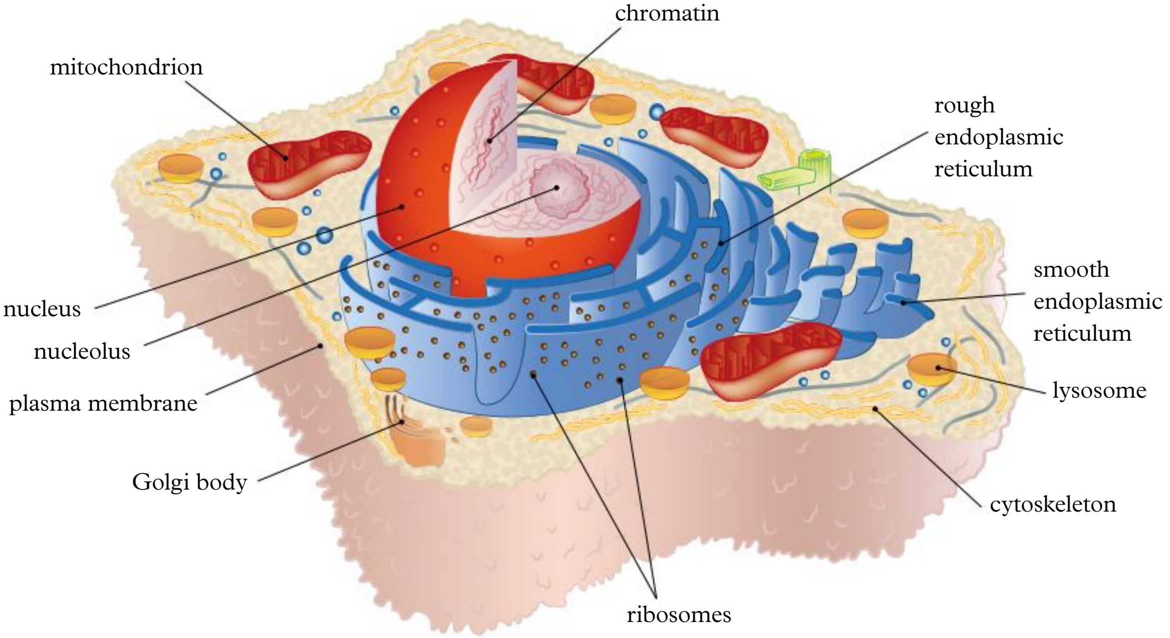


Figure 2 Some key parts (organelles) of an animal cell

A PLANT CELL

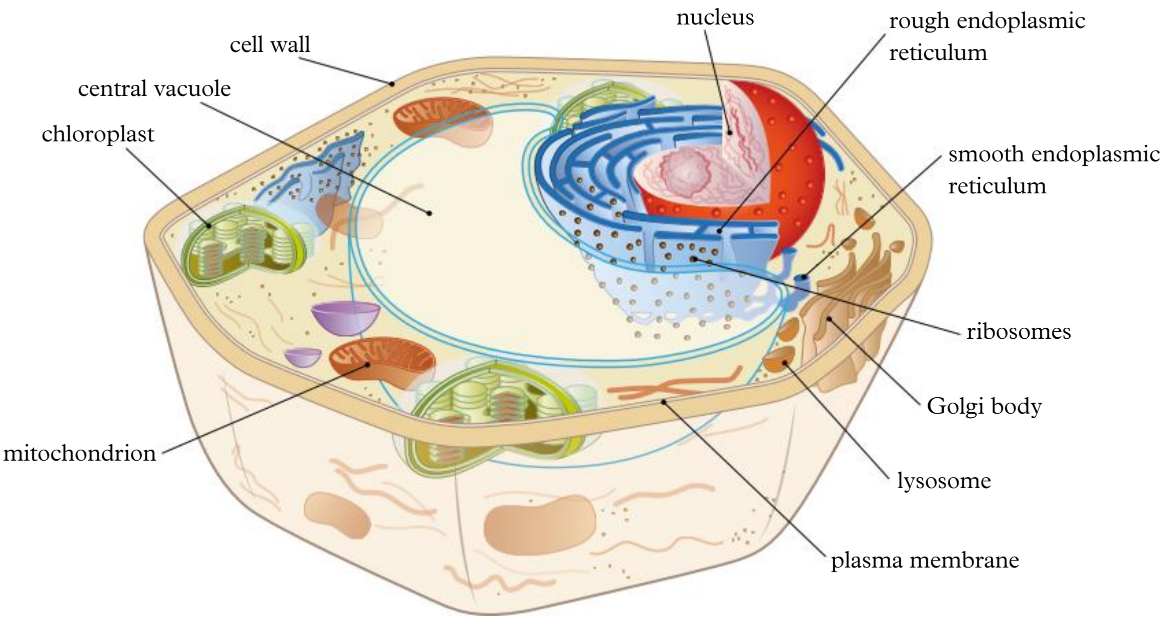


Figure 3 Some key parts (organelles) of a plant cell

A closer look at organelles

Some cells need special areas or **organelles** (mini-organs) to help them do special things (functions). These functions are necessary for the cell to survive. Some organelles, such as ribosomes, are part of the cytoplasm, whereas other organelles are separated from the fluid in the cytoplasm by a membrane, much like the cell membrane. These organelles, such as the nucleus and chloroplasts, are called membrane-bound organelles.

Let's take a closer look at four very important organelles that are in some cells – the mitochondria, ribosomes, chloroplasts and vesicles.

organelle
smaller part of a cell, each one having a different function

mitochondrion
powerhouse organelle of a cell; the site of energy production (plural: mitochondria)

ribosome
cell organelle where protein production takes place

Mitochondria

Mitochondria (singular 'mitochondrion') are the powerhouse of the cell. They are the site of energy production in the cell. There may be several thousand mitochondria in a cell depending on what the cell does. For example, skeletal muscle cells contain a lot of mitochondria to make sure we have enough energy to run and jump when we need to.

Mitochondria are rod-shaped organelles with an inner and an outer membrane (see Figure 4). The inner membrane is folded to increase the surface area of the membrane. An important chemical reaction called cellular respiration occurs inside the mitochondria. This reaction involves the rearrangement of the atoms in glucose (from the food we eat) and oxygen to produce water, carbon dioxide and energy. This energy is used by our bodies to help us move and grow.

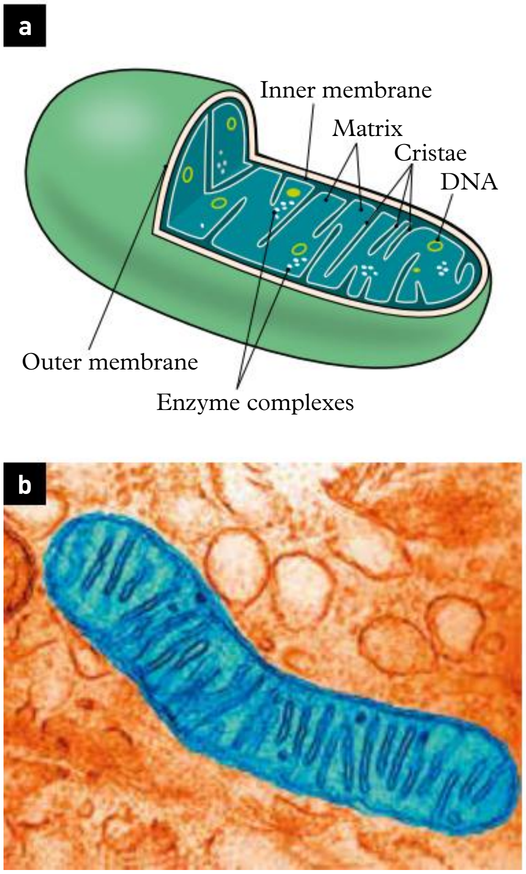


Figure 4 **a** Schematic diagram showing the structure of a mitochondrion **b** Electron micrograph of a mitochondrion

Ribosomes

Ribosomes are where protein is made in the cell. Proteins are small molecules with different roles. There are many different types of proteins. For example, proteins make up hair and nails, or help transport the oxygen that is needed to keep you alive.

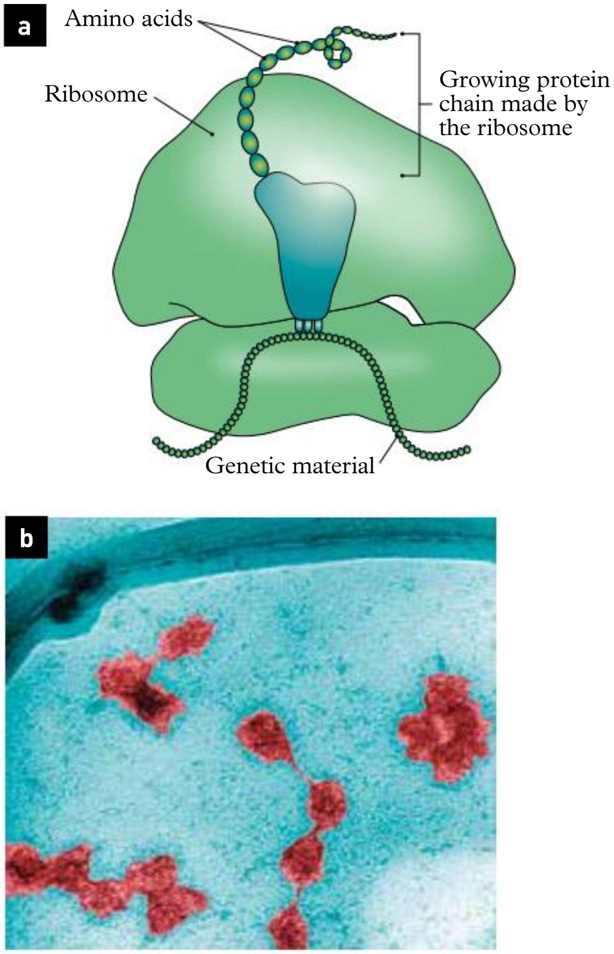


Figure 5 **a** The ribosome decodes genetic material in order to link together the right sequence of amino acids. **b** Electron micrograph of ribosomes

chloroplast
organelle found in plant cells that transforms solar energy into chemical energy

chlorophyll
green pigment found inside chloroplasts that absorbs solar energy and uses it in photosynthesis

photosynthesis
chemical process plants use to make glucose and oxygen from carbon dioxide and water

Chloroplasts

Chloroplasts are only found in plant cells and some unicellular organisms. These organelles are like microscopic solar panels that transform solar energy into chemical energy.

Chloroplasts are usually green because of a molecule called **chlorophyll**. Chlorophyll uses the Sun's light energy to rearrange molecules of carbon dioxide and water into glucose (a sugar) and oxygen. This chemical reaction is called **photosynthesis**.

EXPERIMENT

6.3B: Looking at organelles
Go to page **221**.

EXPERIMENT

6.3C: Measuring cells
Go to page **222**.

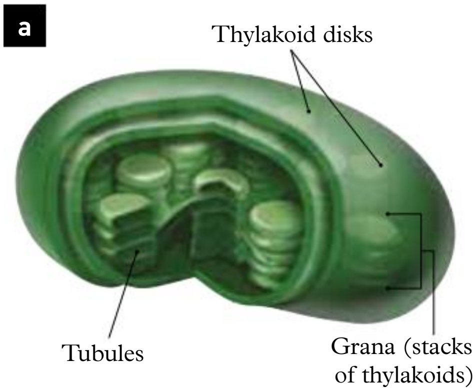


Figure 6 **a** Schematic diagram showing the structure of a chloroplast **b** Electron micrograph of chloroplasts

Vesicles

Vesicles are organelles that are used by plant and animal cells to store water, nutrients and waste products. A membrane surrounds the vesicle, separating the substances from the rest of the cell. Plant cells usually have one large vesicle called a vacuole (see Figure 3). Animal cells may have many small vesicles.

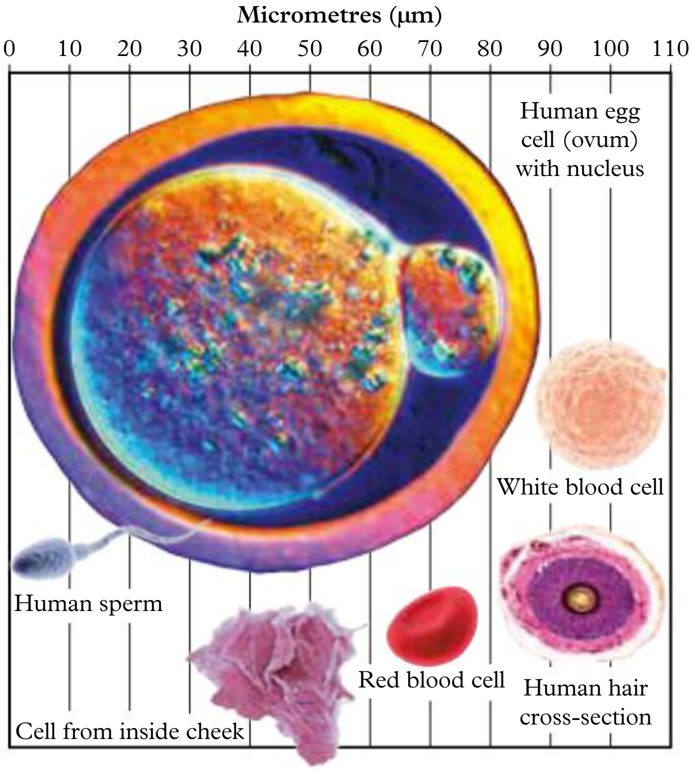


Figure 7 Different types of cells are different sizes and are measured in micrometres (µm). One micrometre is equivalent to one-thousandth of 1 mm.

6.3 Check your learning

Remember and understand

1 **Identify** three organelles that are surrounded by a membrane.
2 **Describe** the function of the cell membrane.
3 **Describe** two roles of proteins in organisms.
4 **Identify** the organelle where cellular respiration occurs.
5 **Identify** three things that are stored in a vacuole.
6 **Describe** the function of chlorophyll.

Apply and analyse

7 **Identify** the reactants (present at the start) and products (present at the end) for the chemical reaction called photosynthesis.
8 **Describe** the features of all living cells. (HINT: Remember MRNGREWW from Year 7.)
9 **Explain** where you would be more likely to find large numbers of mitochondria, in a muscle cell or a bone cell. **Justify** your answer (by explaining the function of mitochondria in a cell, explaining what each cell does and deciding which cell would need the mitochondrial function most).

6.4 All organisms have cells that specialise

In this topic, you will learn that:

- all cells can be broken into two groups, prokaryotes and eukaryotes.
- prokaryotic cells (bacteria) do not have organelles or a nucleus.
- eukaryotes have a nucleus and different organelles that are used to divide them into Kingdoms.

Video 6.4
Eukaryotic cell structure

prokaryotic cell
primitive single-celled organism that has no nucleus

eukaryotic cell
complex cell that contains a nucleus and membrane-bound organelles

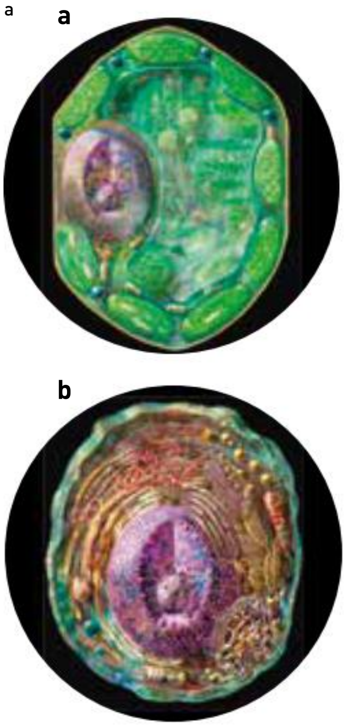


Figure 1 Typical **a** plant and **b** animal cells

Prokaryotes and eukaryotes

Cells are classified into two main groups – prokaryotic cells and eukaryotic cells.

Prokaryotic cells belong in the kingdom Monera. They are the most primitive cellular forms on Earth and are unicellular (single cells). They are much simpler than eukaryotic cells and do not have many of the organelles described in the previous topic. For example, they have no nucleus and their genetic material (DNA) is found free in the cytoplasm. Prokaryotes include all the bacteria found on Earth.

Eukaryotic cells are more complex cells and are found in organisms from each of the other four kingdoms – Animalia, Plantae, Fungi and Protista. Eukaryotic cells keep their genetic material in a nucleus and have the membrane-bound organelles described in Topic 6.3. Most eukaryotes are multicellular. See Table 1 for a list of some of the characteristics of prokaryotic and eukaryotic cells.

Plant cells

When we look at whole organism plants and animals, it's fairly easy to see that they are different. However, once microscopes started to become more powerful, scientists could see differences between the individual plant and animal cells (see Figure 1). Plant cells use their chloroplasts to photosynthesise and need cell walls to provide structure. Many plant cells also store their nutrients in large vacuoles (large spaces surrounded by a membrane).

Fungal cells

Fungi such as mushrooms are often mistaken for a type of plant. Using a microscope, scientists are able to see that fungal cells are different from plant cells. For example, fungal cells don't have chloroplasts, so they cannot photosynthesise, and they don't have large vacuoles filled with liquid. Instead of making their own glucose, fungi such as mushrooms need to absorb their nutrients from the soil.

Table 1 Characteristics of eukaryotic and prokaryotic cells

Characteristic	Kingdom				
	Eukaryotes				Prokaryotes
	Animalia	Plantae	Fungi	Protista	Monera
Number of cells	Multicellular	Multicellular	Multicellular, some unicellular (e.g. yeasts)	Multicellular or unicellular	Unicellular
Cell wall	Absent	Present	Present	Present in some	Present
Genetic material	Present	Present	Present	Present	Present
Nucleus	Present	Present	Present	Present	Absent
Mitochondria	Present	Present	Present	Present	Absent
Chloroplasts	Absent	Present	Absent	Present in some	Absent
Large vacuoles	Absent	Present	Absent	Present in some	Absent
Ribosomes	Present	Present	Present	Present	Present

CHALLENGE

6.4A: Classifying using cells
Go to page **222**.

EXPERIMENT

6.4B: Plant and animal cells
Go to page **223**.

Protists

Protists (Kingdom Protista) are a mixed group of organisms that are mostly unicellular (the whole organism is made up of just one cell). Many live in water, some are photosynthetic (they make their own food, like plants), some eat other organisms and some cause diseases. Depending on where it lives and its food sources, a protist's shape or structure will have evolved to suit its environment. The protists in Figures 2 to 5 have structures particular to their lifestyles.

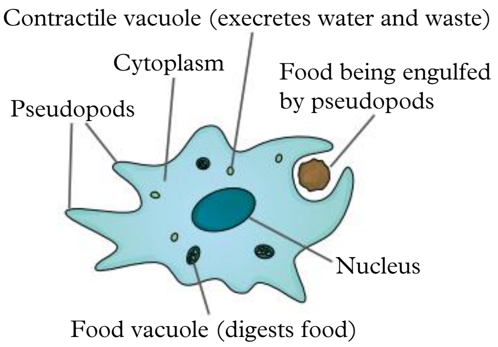


Figure 2 An amoeba can change the shape of its blobby body, creating foot shapes for movement and mouth shapes for swallowing food.

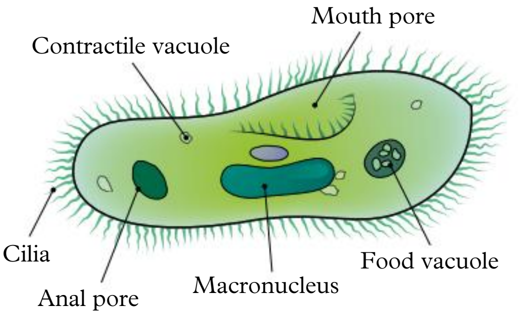


Figure 3 The paramecium moves slowly with lots of tiny hairs called cilia that act like miniature oars.

Animal cells

Single-celled or unicellular organisms, such as bacteria, are made of one cell only. Multicellular organisms, like us, are made of more than one cell and often many billions of cells. The different cells in a multicellular organism communicate and work together to produce a functioning organism. Their different roles in the body mean they have different sizes and shapes. All animal cells have a nucleus and organelles, but no chloroplast or cell wall.

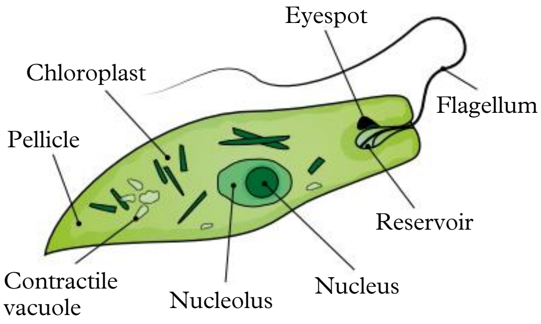


Figure 4 Euglena moves quickly when it needs to, with a bullet-shaped body and a long tail called a flagellum to whip it into action.

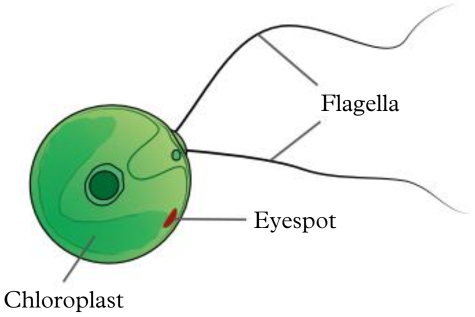


Figure 5 Chlamydomonas has an eyespot to detect light and two flagella to swim.

Figure 6 Cells in kingdom Fungi have cell walls and nuclei, but no chloroplasts.

6.4 Check your learning

Remember and understand

1 **Describe** an example of a unicellular organism and a multicellular organism.

2 **Describe** the two main differences between eukaryotic and prokaryotic organisms.

3 **Identify** where the genetic material is found in a prokaryotic cell.

4 Use Table 1 to **identify** the kingdom that is often referred to as 'the rest' of the cells.

Apply and analyse

5 Table 1 shows that plant cells contain chloroplasts. Although a typical plant cell contains chloroplasts, they are not found in all plant cells.

a **Explain** why some cells in a plant root may lack chloroplasts.

b **Identify** the part of a plant where you would expect to find cells with chloroplasts.

Evaluate and create

6 Draw a cell that would be found in a mushroom (eukaryotic fungal cell). Label all of the organelles.

6.5 Bacteria are single-celled organisms

In this topic, you will learn that:

- non-dangerous bacteria that live in or on our body are called natural flora.
- pathogens are cells that cause disease in other organisms.
- infectious pathogens can be passed between organisms.
- bacteria reproduce through binary fission.
- viruses are non-living because they cannot reproduce alone.

Video 6.5
Bacteria are single-celled organisms

Unicellular organisms, such as bacteria, are living in and around us all the time. The average adult human has 1 kg of non-human life inside their large intestine alone. Some microbes (microscopic organisms) are essential for keeping our body healthy and working correctly. Others can be deadly.

Natural flora

The microbes that live happily on or in our bodies are referred to as **natural flora**. The careful balance between natural flora and the microbes in our environment is important to our health. The right amount of natural flora will protect us against foreign invaders, while too much of the natural flora can actually make us ill. Bacteria in our intestines help our bodies digest food and provide vitamins to keep us healthy. The bacteria on our skin act as a protective coating, preventing disease-causing bacteria from growing.

Microbes causing disease

We have all been sick at some stage in our lives. Some forms of sickness are caused by pathogens. A **pathogen** is a micro-organism that can potentially cause a disease. With **infectious diseases**, the pathogen may be passed from one organism to another. Such diseases are described as contagious, meaning they can spread from one organism to another. Pathogens always live on a host organism, such as a human, animal or plant. You will be investigating pathogens in more detail in Year 9. The **symptoms** of a disease are the changes that occur to a host due to the disease.

natural flora
microbes that live happily in our bodies

pathogen
microbe that can potentially cause a disease

infectious disease
disease caused by the passing of a pathogen from one organism to another; also known as contagious disease

symptoms
the physical or mental signs of a disease

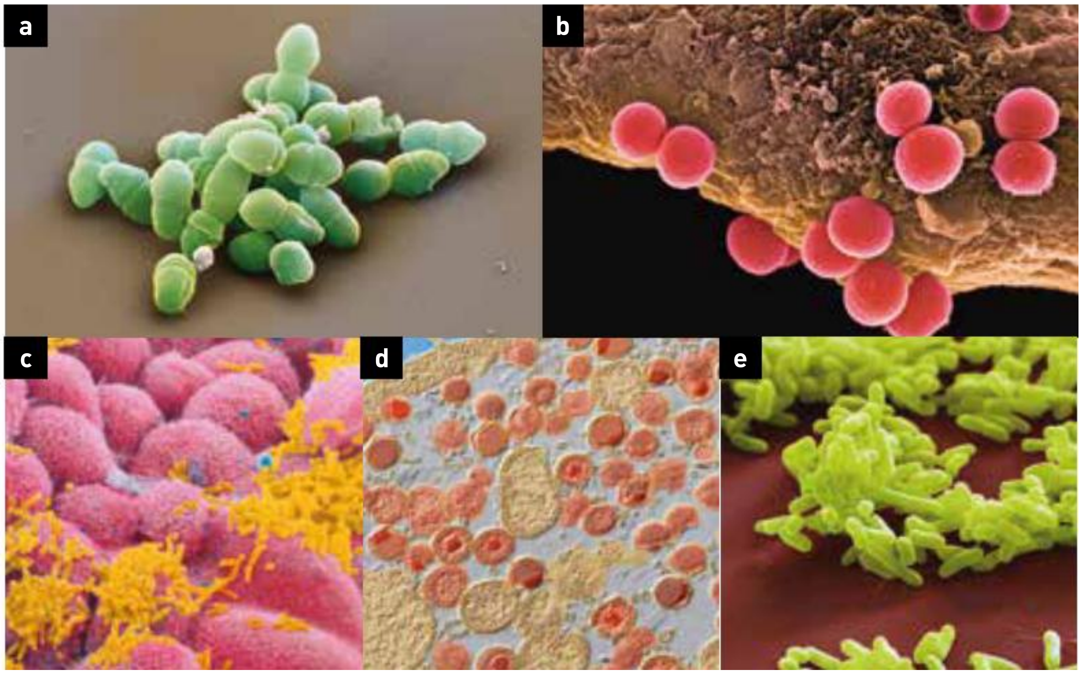


Figure 1
a *Staphylococcus epidermis* (natural flora of the skin)
b *Staphylococcus aureus* (a bacterium) in the hair
c *Haemophilus influenzae* (a bacterium) in the nose
d *Chlamydia trachamates* (a bacterium) in the eye
e *Esherichia coli* (bacteria) in the intestines

EXPERIMENT

6.5: Microbes all around
Go to page **224**.

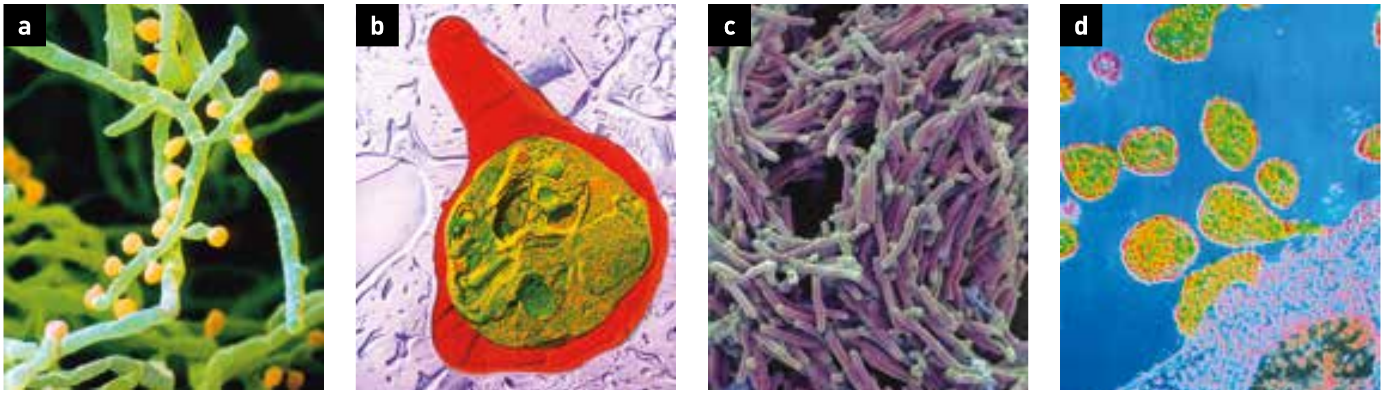


Figure 2 **a** *Trichophyton mentagrophtes* – cause of ringworm and tinea **b** A red blood cell infected with malarial parasites **c** Tuberculosis bacteria **d** Rubella virus

Harmful microbes may be bacteria, fungi, protista or viruses. All these microbes can invade the body and cause disease. You will probably be familiar with some diseases caused by harmful microbes. Fungi can cause infections such as tinea, which is also known as athlete's foot, and ear infections. Protists can cause malaria and dysentery. Bacteria cause diseases such as tuberculosis (also known as TB), pneumonia, Legionnaires' disease and cholera. Viruses can cause diseases such as Covid-19, the common cold and flu, measles and herpes.

Viruses

Viruses are considered by most scientists to be non-living pathogens. Viruses cannot survive and reproduce outside a host cell. Instead, they need to invade a cell and use the cell's organelles to reproduce.

Viruses (such as influenza and coronaviruses) are responsible for most of the common colds that we experience. They cannot be controlled by antibiotics because they're hiding inside our cells. This also makes it much harder for our own immune cells to find and fight them, so our best defence is to rest, eat a healthy diet and let the cells in our body concentrate on getting rid of the viruses by themselves.

Bacterial growth

Bacteria reproduce using a process called **binary fission** (binary = two; fission = split). As the name suggests, a bacteria cell grows slightly larger and then splits in two. This is a very quick process, sometimes taking as little as 20 minutes. This can be represented on a graph such as the one in Figure 3.

Most bacterial growth is stopped at temperatures below 4°C and above 60°C. For this reason, your fridge should be below 4°C and cooked food waiting to be served should be stored above 60°C.

binary fission
a form of asexual reproduction used by bacteria; the splitting of a parent cell into two equal daughter cells

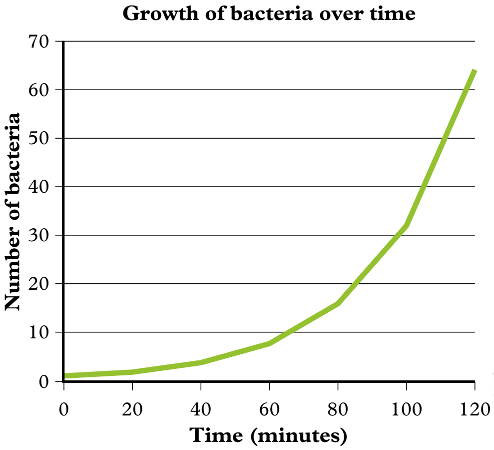


Figure 3 The number of bacteria cells can double every 20 minutes.

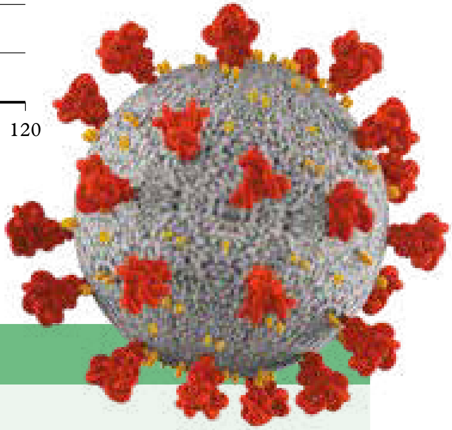


Figure 4 Covid-19 is a disease caused by a type of virus called coronavirus. Viruses are much smaller than cells.

6.5 Check your learning

Remember and understand

1 **Identify** the type of micro-organism that your digestive system relies on.

2 **Define** the term 'natural flora'.

3 **Describe** a situation where natural flora can be harmful to our bodies.

4 **Define** the term 'pathogen'. **Identify** the four main groups of pathogens.

5 **Explain** why a virus is not considered to be living.

Apply and analyse

6 It is not recommended that food be left out of the fridge for more than 3 hours. Use the definition of binary fission to **explain** why.

6.6 Fungal cells can save lives

In this topic, you will learn that:

- some fungal cells protect themselves from bacteria by producing antibiotics.
- fast-producing bacteria can become resistant to antibiotics.
- 'superbugs' are bacteria that are resistant to many types of antibiotics.

Figure 1 A type of penicillin can grow on orange peels.

Have you ever scratched yourself on a bush, or pricked yourself with a needle? Before the discovery of antibiotics, such a simple break in the skin could have been enough to kill you.

Figure 2 Alexander Fleming

The discovery of penicillin

It has been accepted for over 3000 years that some fungal cells could kill bacteria. In 1928, Alexander Fleming is credited with discovering the specific chemical that was responsible for this.

Fleming was trying to grow bacteria on special agar plates as part of his research. Bacteria usually grow very well across the top of agar plates. However, this day Fleming failed to clean up after his experiment and left an agar plate open on his bench before leaving for a holiday. When he returned from his break, a small spot of mould had started growing in the centre of the plate. All around the mould was a clear circle where the bacteria were unable to grow. Fleming concluded that the mould (*Penicillium*) was producing a molecule that prevented the bacteria from growing. The molecule, which was named penicillin, had the ability to stop bacterial growth by preventing the bacteria repairing or making a new cell wall.

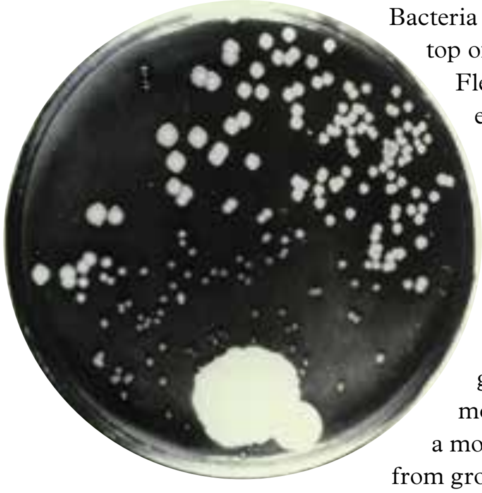


Figure 3 Some moulds are able to prevent bacterial growth.

Producing penicillin

It took ten more years and the work of Howard Florey (an Australian) and Ernst Chain to develop a way to separate the penicillin and produce it on a large scale. They were part of a team of specialists brought together to grow the mould, extract the penicillin, purify it and trial its treatment on patients.

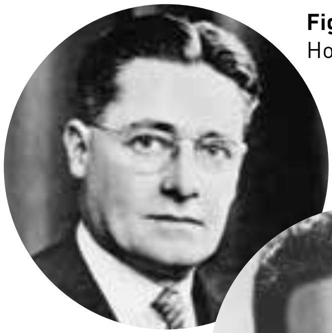


Figure 4 Howard Florey

Figure 5 Ernst Chain

Their most important experiment occurred in May 1940. Eight mice were infected with streptococcal bacteria, and four of the mice were treated with the newly extracted penicillin. These four mice survived, while the mice without the penicillin died.

This led the researchers to trial the penicillin on their first patient. Albert Alexander's whole face was swollen after being scratched by a rose thorn. One eye had been removed while the other had been lanced to drain the pus. Within one day of being given penicillin, he started to improve. Unfortunately, Fleming's group did not have enough penicillin to finish the treatment and the patient suffered a relapse and died. The researchers tried treating children next, as smaller doses could be used and the treatment could last longer. Eventually their purification methods and resulting treatment were successful. They were awarded a Nobel Prize in 1945 for their work.

The use of penicillin as an antibiotic revolutionised health care and the lives of many people who, without such treatment, would have died from bacterial infections.

Overuse of antibiotics

There are now many more different antibiotics available, most of which are extracted from fungi. The overuse of antibiotics is a cause for concern. Because bacteria reproduce quickly, some strains of bacteria are becoming 'resistant' to treatment. That is, they are not affected by antibiotics. Scientists are continually searching for new types of natural and artificial antibiotics to treat these new 'superbugs' that are resistant to all known antibiotics.

A dose of antibiotics destroys not only the harmful bacteria, but also the good bacteria in your body, so they should only be used to treat bacterial infections when absolutely necessary.

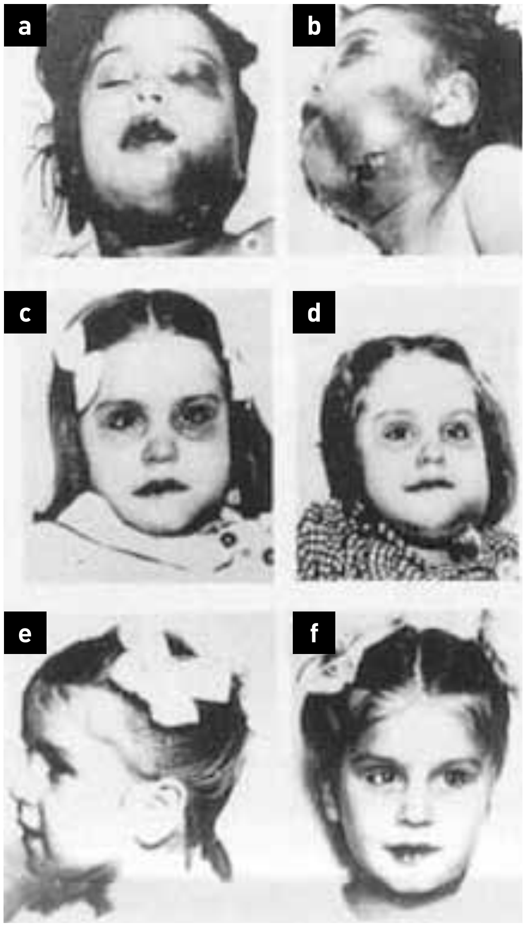
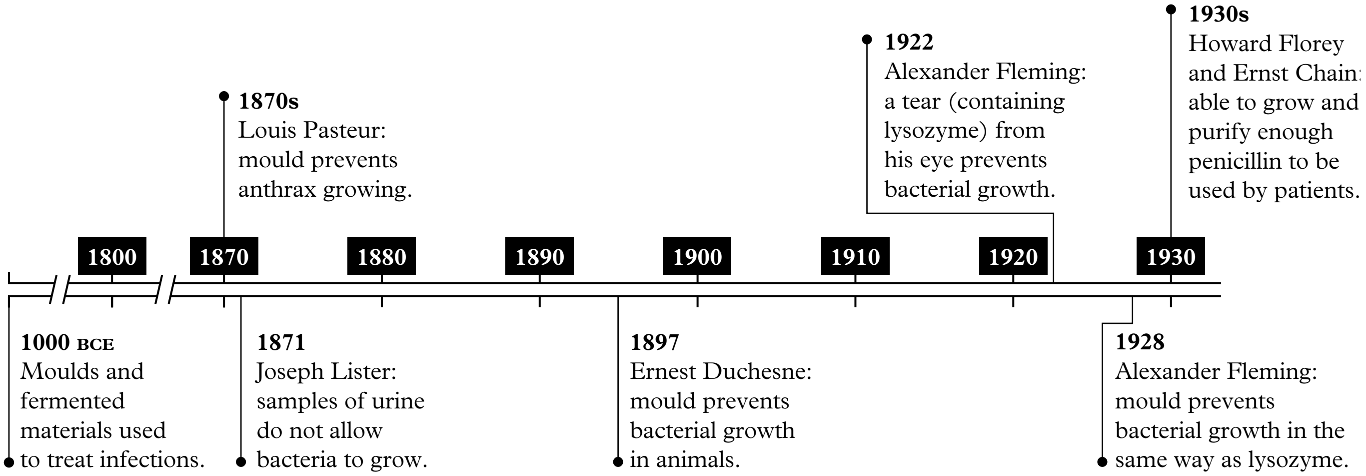


Figure 6 These photos from 1942 show the improvement of a child after penicillin treatment for a bacterial infection.
a, b Before treatment
c Four days after treatment
d Nine days after treatment
e, f Fully recovered



1000 BCE Moulds and fermented materials used to treat infections.

1870s Louis Pasteur: mould prevents anthrax growing.

1871 Joseph Lister: samples of urine do not allow bacteria to grow.

1897 Ernest Duchesne: mould prevents bacterial growth in animals.

1922 Alexander Fleming: a tear (containing lysozyme) from his eye prevents bacterial growth.

1928 Alexander Fleming: mould prevents bacterial growth in the same way as lysozyme.

1930s Howard Florey and Ernst Chain: able to grow and purify enough penicillin to be used by patients.

Figure 7 Penicillin timeline

6.6 Check your learning

Remember and understand

1 **Define** the term 'antibiotic'.

2 **Contrast** fungi and bacteria.

3 Fungi usually grow best at 22°C. **Explain** why leaving the agar plate on the bench accidentally helped Fleming to make his discovery.

Apply and analyse

4 **Explain** why Florey and his group of scientists did not give penicillin to four of their mice.

5 **Explain** why fungi might need to protect themselves from bacteria.

Evaluate and create

6 'The most exciting phrase to hear in science, the one that heralds discoveries, is not "Eureka" but "that's funny …"' Use Fleming's discovery to **explain** this quote from Isaac Asimov.

REVIEW 6

Multiple choice questions

1 **Identify** which of the following is *not* found in an animal cell.
- A mitochondria
- B a cell wall
- C cytosol
- D a nucleus

2 **Identify** which important process takes place in the mitochondria of a cell.
- A photosynthesis
- B excretion
- C cellular respiration
- D cell division

3 **Identify** the term that describes the organism that catches the disease.
- A a cell
- B a pathogen
- C a host
- D an organism

Short answer questions

Remember and understand

4 **Identify** the first person to describe a cell.

5 **Describe** the benefit of using a stain when viewing some specimens.

6 **Describe** the cell theory.

7 **Identify** two types of microscopes.

8 **Explain** why a specimen needs to be very thin to be viewed under a light microscope.

9 **Compare** a mitochondrion and a chloroplast.

10 **Contrast** fungal cells and bacterial cells.

11 **Define** the following words:
- a nucleus
- b mitochondrion
- c chloroplast
- d binary fission
- e pathogen.

12 Ribosomes are found in every cell on Earth. **Describe** the function that ribosomes perform in cells.

13 **Distinguish** between the terms ‘unicellular’ and ‘multicellular’. Provide two examples of each.

Apply and analyse

14 **Explain** why antibiotics cannot be used to treat Covid-19.

15 A cell membrane is ‘partially permeable’. This means that only certain substances can cross the membrane. **Identify** some substances that would need to get into the cell and some that would need to get out.

16 **Explain** why unicellular organisms are always tiny, and why multicellular organisms are made up of many cells instead of one large cell.

17 **Explain** why a doctor will not prescribe antibiotics if you are sick with a cold or flu.

18 Animal cells have mitochondria, while plant cells have both mitochondria and chloroplasts. **Explain** this difference.

19 Light microscopes allow you to view living cells. **Describe** why the cells need to be thin to be seen down a light microscope.

20 **Calculate** the magnification of a cell that is viewed with a ‘x40’ objective lens and a ‘x10’ eyepiece lens.

Evaluate

21 Two students prepare slides from different sections of a spring onion under a light microscope in their school laboratory. James views a section of the green leafy part and observes many chloroplasts within each cell, but has difficulty identifying a nucleus in each cell. Emily views a section of the white stem of the plant. She comments that a nucleus is clearly visible in most of the cells, but does not identify any chloroplasts.
- a **Determine** why James identified many chloroplasts within each cell when they appeared to be absent from the cells viewed by Emily.
- b Emily commented that she could identify a nucleus in most cells. **Evaluate** whether it is possible for a plant cell not to have a nucleus (by describing the function of a nucleus, describing the importance of a nucleus to the cell staying alive and deciding if it is possible for a plant cell to live without a nucleus).

22 Write a very short creative story about a virus. Your story needs to be from the point of view of a cell. The first line of your story is: ‘Once upon a time, a virus arrived for an uninvited visit’.

23 **Identify** the microscope most likely to have created the images in Figure 1. **Justify** your decision (by describing the features in the picture that are unique and deciding which microscope would allow these features to be seen).

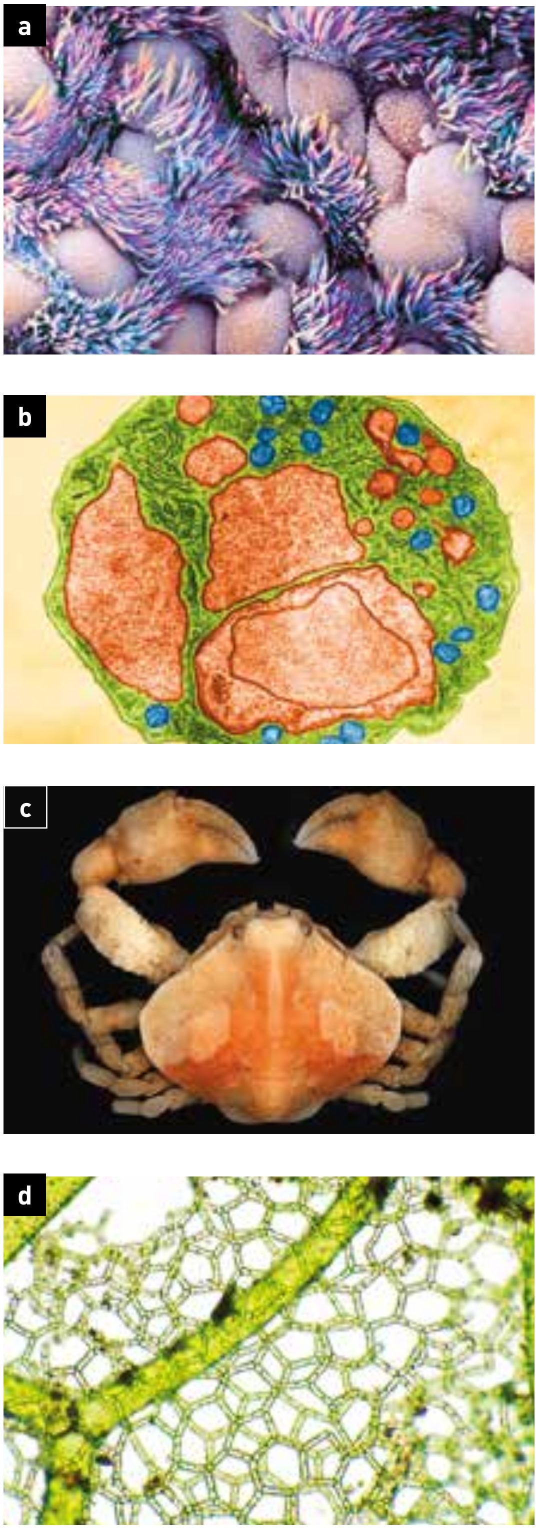


Figure 1 Microscope images

24 Use the lenses from an old pair of reading glasses or a magnifying glass to create a model of a microscope. Describe how your model is similar to and different from Hooke's microscope and modern compound microscopes.

25 **Discuss** how our understanding of cell structure and function has changed with the development of the microscope.

Social and ethical thinking

26 **Explain** why a doctor should not prescribe antibiotics for a viral infection by describing:

- a the effectiveness of antibiotics for making the person healthy
- b the long-term effects of overprescribing antibiotics on antibiotc resistance.

27 Stem cells are cells in multicellular organisms that haven't become specialised yet – they're like blank canvases. Scientists use stem cells to help with the understanding of how diseases happen, and to create healthy cells to replace damaged or diseased cells in the human body. Scientists and researchers also use stem cells to test new drugs, instead of having to use humans or animals. Explain why it might be more ethical to use stem cells to test new drugs, instead of using human or animal testing.

28 A patent is a right or title that is given to the inventor of something useful, to stop other people from making or selling the thing that has been invented. Ernst Chain wanted to get a patent on penicillin when it was first produced; however, Howard Florey thought it would be unethical to do so because it is a life-saving drug. Evaluate both sides of the argument to patenting penicillin, from the perspective of both Ernst Chain and Howard Florey.

Critical and creative thinking

29 Similes are often used in creative writing to compare two things using the words 'like' or 'as'. **Explain** the similarities that allow these similes to be used.

- a Cells are like building blocks.
- b The nucleus is like a control centre.
- c The mitochondrion is like a power station.

30 **Describe** how our understanding of how living things function changed with the development of the microscope.

Research

31 Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

» Linking big concepts

Think of a creative way to represent the six big concepts about cells discussed in this chapter. You might use a concept map or mind map with each of the questions as major bubbles. You could choose to use diagrams only or draw a picture that shows all the aspects of the particles of life. The method of presentation that you select must enable you to share your ideas with others.

» Discovery of penicillin

The discovery of penicillin was considered an important factor behind the outcome of the Second World War. Soldiers who were injured on the battlefield could be mended, given a shot of penicillin, and returned to the battlefield instead of having limbs amputated. Write a newspaper article describing the importance of this major discovery.

» Plant cells

Plants do not have lungs to breathe. Instead they have small pores called stomata, which allow air to pass in and out of the plant. These stomata are made up of two guard cells that can change their shape. Find out how stomata open and close in response to changing environmental conditions. Describe the conditions that allow the stomata to open and close. Describe how the shape of the guard cells assists the opening and closing of the pore.

Reflect

The table below outlines criteria for successfully understanding Chapter 6 ‘Cells’. Once you have completed this chapter, reflect on your ability to do the following:

	I can do this.	I cannot do this yet.
Explain the key concepts of the cell theory and describe the surface area to volume ratio.	☐	☐ Go back to Topic 6.1 ‘All living things are made up of cells’ Page 112
Compare and contrast electron microscopes and light microscopes, and stereomicroscopes and compound light microscopes. Calculate magnification and demonstrate the ability to focus a compound light microscope.	☐	☐ Go back to Topic 6.2 ‘Microscopes are used to study cells’ Page 114
Describe the functions of the cell membrane, cytoplasm, DNA, mitochondria, ribosomes, chloroplasts and vesicles. Identify the key differences in structures of plant and animal cells.	☐	☐ Go back to Topic 6.3 ‘Plant and animal cells have organelles’ Page 116
Describe the key differences between and provide examples of prokaryotic and eukaryotic cells.	☐	☐ Go back to Topic 6.4 ‘All organisms have cells that specialise’ Page 120
Describe the differences between natural flora and pathogens. Explain the benefits of natural flora to human health.	☐	☐ Go back to Topic 6.5 ‘Bacteria are single-celled organisms’ Page 122
Describe the development of penicillin and explain the problems associated with the overuse of antibiotics.	☐	☐ Go back to Topic 6.6 ‘Fungal cells can save lives’ Page 124

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Launch a quiz for your students on key concepts in this chapter.

CHAPTER
7
SURVIVING

How does our body work?

What if?

Heartbeats

What you need:

Stopwatch

What to do:

1 Sit down for 2 minutes.
2 Measure the number of times you breathe in every minute.
3 Measure the number of times your heart beats in every minute.
4 Record your measurements in a table.

What if?

» What if you ran around the oval for 5 minutes? How would your heart rate and breathing rate change?
» What if you listened to music with a slow beat for 5 minutes?
» What if you listened to music with a fast beat for 5 minutes?

7.1 Systems are made up of cells, tissues and organs

In this topic, you will learn that:

- groups of cells that do a similar task are called tissues.
- groups of tissues that work together are called organs.
- when groups of different organs work together, they are called a body system.
- anatomists study how the body works.

Figure 1 The process of mummification required organs to be removed. They were sealed in Canopic jars (covered urns).

connective tissue	the group of cells that provide connections to other parts of the body
muscle tissue	the group of cells that allow the body to move
nervous tissue	the group of cells that pass on electrical messages
epithelial tissue	the group of cells that cover and protect the body
system	a group of organs that work together for a purpose
organ	a group of tissues that work together for a purpose

How did the first scientists learn about the body?

The very first anatomists in the ancient Egyptian city of Alexandria performed dissections in the third century BCE to investigate how the human body worked.

The Egyptians were very clean and quite fearful of illness. They believed that illness was caused partly by evil spirits, so doctors were also part shaman (spiritualists).

Perhaps because of this fear of illness, the Egyptians made many medical advances and learnt a lot about the human body. Much of this knowledge about human body systems and organs likely came about from observations made during the mummification process. As part of this process, the Egyptians removed key organs from the body because they contained so much liquid that they interfered with mummification. (These organs were subsequently placed in Canopic jars to journey separately into the afterlife.)

Leonardo da Vinci

Leonardo da Vinci is famous as a painter and architect, but he also studied the human body. Da Vinci began studying the human body through life drawing (drawing people standing in front of him) and by attending the public dissections that were held by the medical schools. He was involved in both human and animal dissections and, from these, he created beautiful and highly accurate drawings.

Tissues

The development of the microscope by Robert Hooke in the 1600s led anatomists to examine how cells work together to form the different systems in the body. They found that some similar looking cells work together to carry out a particular job or function (tissues). These tissue functions are broken into four types.

Connective tissue includes blood cells, fat cells, bone cells or tendons and ligaments. These cells are all surrounded by a non-living material called a matrix. This matrix can be liquid or solid. For example, cells in the bone marrow are surrounded by solid bone, and cells in the blood are surrounded by liquid.

The cells in **muscle tissue** are able to cause parts of the body to move. For example, the muscle cells in the heart enable it to beat, while the muscle cells connected to the skeleton enable us to move.

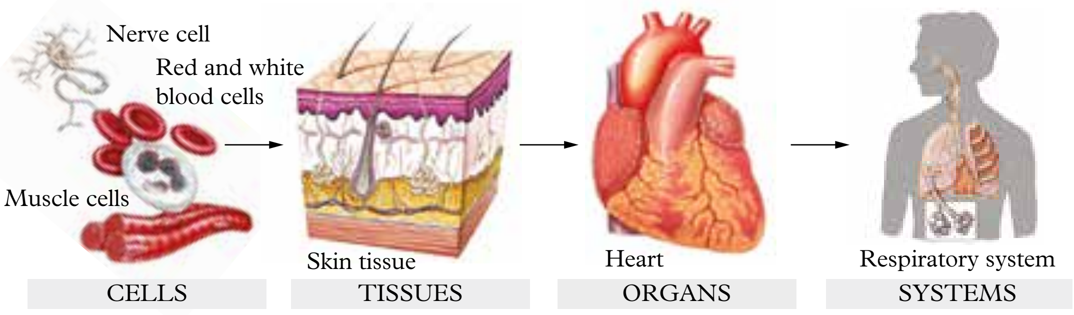
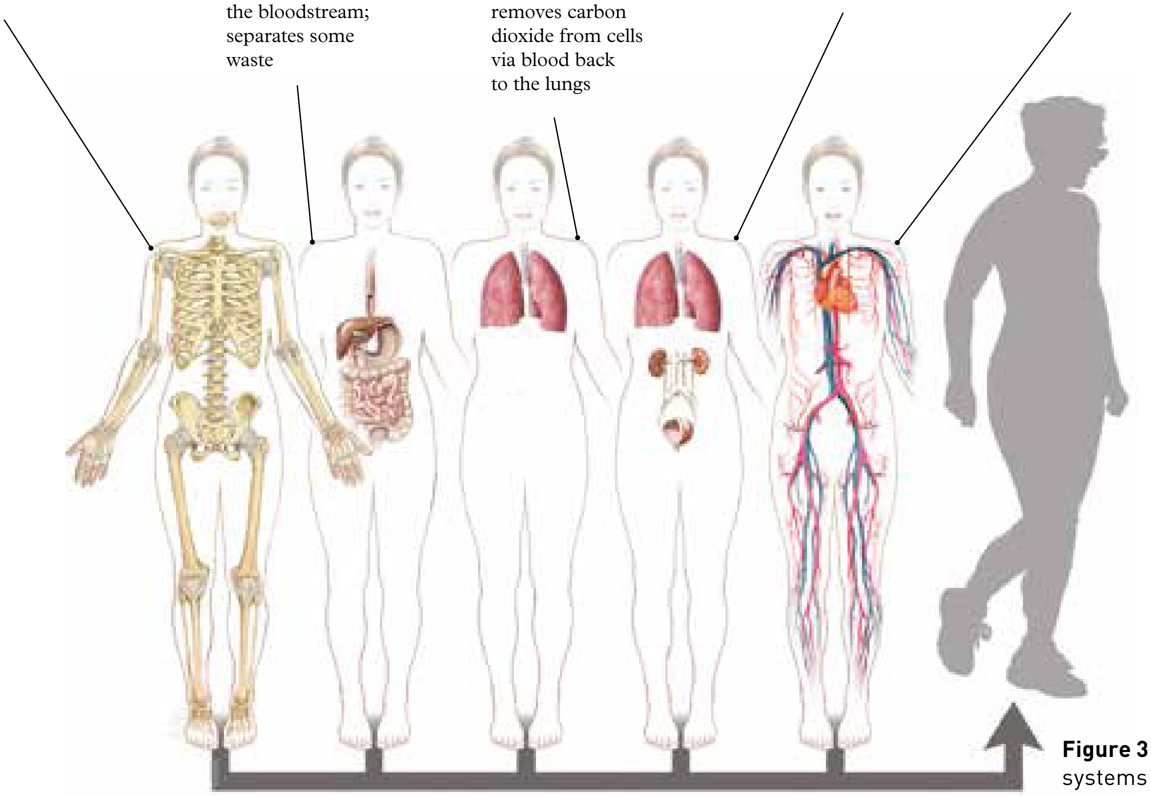


Figure 2 The different levels of organisation in the body

CHALLENGE
7.1: Brown paper body brainstorm
Go to page 225.



Skeletal system
All bones, including spine, skull, pelvis and ribs

Gives body structure and supports and protects other organs; provides attachment for muscles

Digestive system
Mouth, stomach, small intestine, large intestine, rectum and anus

Breaks down food into substances small enough to be absorbed into the bloodstream; separates some waste

Respiratory system
Lungs, windpipe and diaphragm

Filters oxygen from the air and transfers it to the blood so that it is taken to all other parts of the body; removes carbon dioxide from cells via blood back to the lungs

Excretory system
Kidneys, liver, bladder, urethra, skin and lungs

Processes and filters out wastes and controls the amount and content of body fluid

Circulatory system
Heart, veins and arteries

Carries oxygen and nutrients to cells and waste materials away from cells via the blood

Figure 3 Our body systems work together.

Nervous tissue contains cells that allow the different parts of the body to pass on messages. This occurs though neuronal cells.

The cells that make up **epithelial tissue** are usually large and flat, allowing them to cover a large surface. Their role is to provide a barrier between the outside of the organism and the vulnerable inside cells. Epithelial tissues help protect the internal parts of the body from damage, bacteria and water loss.

Organs

When the four types of tissues work together to do a particular job, they are called an organ. Your heart is an example of an **organ**. It is lined with epithelial tissue to protect the surface. It contains blood (connective tissue) and nervous tissue to help the cells to communicate and it contains muscle tissue to help it to move and beat.

The heart is connected to another organ: blood vessels that also contain all four types of tissue. When groups of different organs work together to perform a particular function, they are called a **system**. These systems work together to maintain the health of an organism.

7.1 Check your learning

Remember and understand

1 **Define** the terms ‘cells’, ‘tissues’ and ‘organs’.

2 **Explain** why the Egyptian shamans studied how the body worked.

3 **Describe** why Leonardo da Vinci is so famous.

Apply and analyse

4 **Explain** how cells, tissues, organs and systems are linked.

5 Select an organ and **explain** how the four types of tissue work together so that the organ can function.

6 Use Figure 3 to **explain** how the circulatory system and digestive system work together.

7 **Explain** why surgeons need a thorough understanding of anatomy.

7.2 The digestive system is made up of organs

In this topic, you will learn that:

- digestion is the process of breaking down food so that it can be used by the body.
- physical digestion occurs when the body manually breaks apart food particles.
- chemical digestion occurs when enzyme molecules break the chemical bonds in food.
- nutrients are absorbed in the intestines.

Video 7.2
The digestive system

Interactive 7.2
The digestive system

digestion
the process of breaking down food into nutrients

chyme
a mixture of acid, enzymes and digested food that leaves the stomach

peristalsis
the process of swallowed food being moved along the digestive tract by a wave of contractions, as the muscles behind the food squeeze tight and the muscles in front of the food relax, causing the food to move along the oesophagus or intestines

Figure 1 Biscuits are physically digested by teeth and chemically digested by enzymes in saliva.

Digestion is the process where food (and drink) is broken down and absorbed into your blood for transport to your cells. The food we eat provides us with the energy to stay alive and provides the building materials for growth and repair.

Digestion

Your digestive tract is made up of a group of organs in the digestive system that form a tube travelling from your mouth to your anus. Along the way, food is broken down and absorbed across the intestinal walls into the blood. The internal walls of the intestines are wrinkly to increase their surface area. This means there is a lot of area for nutrients to be absorbed into the blood. Food that is not needed by the body (such as fibre) remains in the digestive tract until the end, where it is released into the toilet.

Physical digestion

Your teeth are responsible for the physical breakdown of your food. There are three main types of teeth in your mouth that do this work. The front ones are called incisors, the pointy teeth next to the incisors are called canines and the rest of your teeth, which are flatter, are called molars. Each type of tooth has an important function. The front incisors cut your food when you bite down, the canine teeth are for tearing meat, while the molars are good for chewing and grinding food into smaller pieces. You also have a large muscular organ called a tongue that can push upwards, sideways and backwards. When you swallow your food, the muscles behind the food squeeze tight, and the muscles in front of the food relax. This forces the food to move in a process called **peristalsis**.

Chemical digestion

The mouth is also where saliva is found. Saliva is mostly water, but also contains different types of enzymes. Enzymes are chemicals that can speed up a reaction (see Chapter 5). In the digestive system, enzymes encourage the lumps of food to break down into nutrients that are small enough to be taken in or absorbed through the cell membrane.

The stomach contains a mixture of gastric juices to help digest the food you have eaten. These juices include acid that kills any bacteria that may be in the food, and an enzyme that digests the protein (found in meat) in your meal. The cells lining the inside of the stomach produce mucus to stop the acid burning the stomach walls. The resulting mixture of acid, enzymes and partially digested food is called **chyme**.

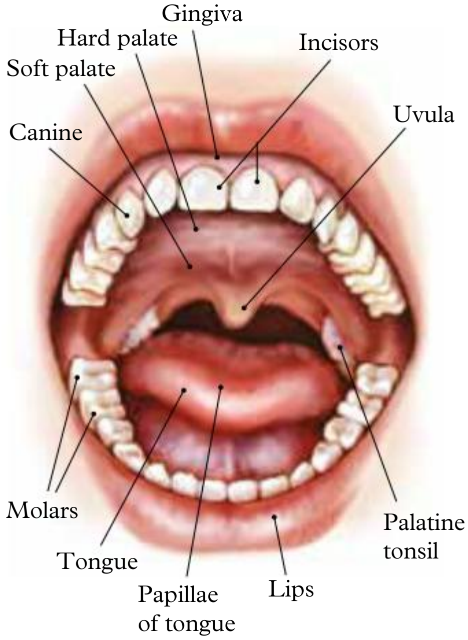


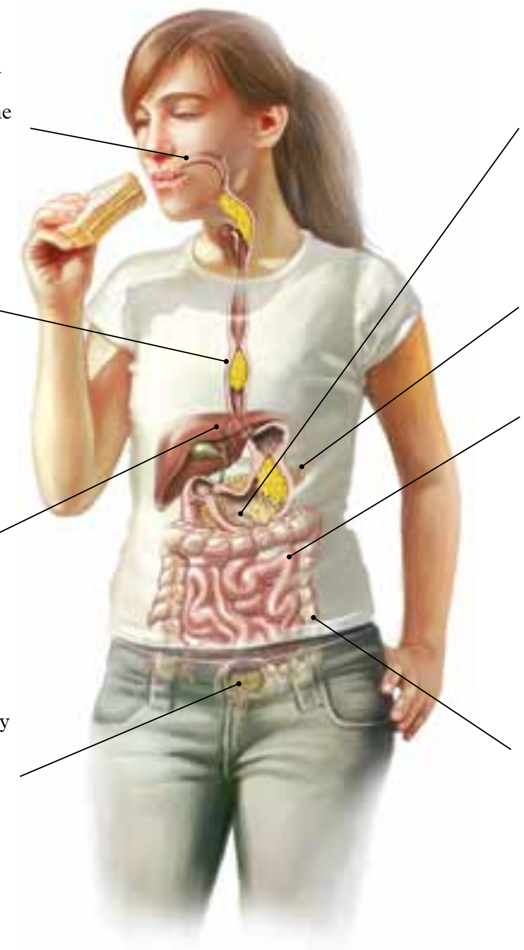
Figure 2 The teeth and mouth physically break down food.

EXPERIMENT

7.2A: Digesting protein
Go to page **226**.

EXPERIMENT

7.2B: What if an enzyme was boiled?
Go to page **227**.



Teeth and mouth
The teeth are responsible for the physical breakdown of food and the tongue is important in pushing the food towards the teeth. Salivary glands make saliva, which contains enzymes to start chemical digestion.

Oesophagus
The oesophagus is a tubular muscle that forces food down to your stomach in a process called peristalsis.

Liver and gall bladder
The liver makes a mixture of chemicals called bile, which is used to digest fat and neutralise (deactivate) stomach acid. The bile is stored in the gall bladder until food reaches the small intestine. Bile is then released into the small intestine through a tube called the bile duct. Food does not travel through the liver.

Rectum and anus
The rectum is the final part of the journey for what is now solid, undigested food, or faeces. The rectum stores faeces until it starts to become full. As the rectum starts to stretch, messages are sent to the brain to make you realise that you need to go to the toilet. Rectal muscles push the faeces out of the ring of muscle at the end of the rectum called the anus.

Stomach
The stomach stores food for about 3 hours while it uses gastric juice (stomach acid) to help digest the food. The food in your stomach looks nothing like what you ate for dinner. It is very runny, warm and smelly and has a totally different taste. This mixture is called chyme.

Pancreas
The pancreas makes pancreatic juice, which contains a mixture of digestive enzymes and also neutralises stomach acid. Food does not travel through the pancreas.

Small intestine
The small intestine is called 'small' because it is quite narrow. If you laid a small intestine out in a straight line, it would be approximately 5 m long. The intestines are really important because they absorb the nutrients that all the cells of the body require. The ability to absorb nutrients is increased by projections, called villi, along the inner wall of the intestine that increase the surface area for absorption. Bacteria in the small intestine also help with digestion. Chyme takes about 5 or 6 hours to pass through the small intestine.

Large intestine
The large intestine is also called the colon and is wider but shorter than the small intestine. The large intestine is approximately 1.5 m long. By the time the chyme reaches the large intestine, most nutrients have been absorbed into the bloodstream. However, some vitamins are absorbed from the large intestine. Water is also absorbed into the bloodstream from the large intestine. Chyme stays in the large intestine for up to 14 hours, or sometimes longer.

Figure 3 The structure of the digestive system is shown here with key parts labelled.

Absorbing nutrients

Most nutrients are absorbed in the small intestine. The inside of the small intestine is full of ridges called **villi**. These ridges increase the surface area that the nutrients pass over. This allows more time for all the nutrients to be absorbed into the intestinal cells.

villi
small ridges in the small intestine that absorb nutrients from the digestive system

7.2 Check your learning

Remember and understand

1 **Identify**, in order, the organs of the digestive system that food moves through, from the mouth to the anus.

2 **Describe** how saliva makes it easier to eat dry biscuits.

3 **Contrast** mechanical and chemical digestion.

4 **Contrast** the digestive system and the digestive tract.

5 **Identify** the organs that are involved in digestion but do not have food passing through them.

Apply and analyse

6 Teeth would look very nice if they were all the same size and shape. **Explain** the advantage of having different types of teeth in your mouth.

7 **Describe** some tools that may work the same way as incisors, canines or molars.

8 **Explain** the advantage of the intestine having villi.

Figure 4 Apples are easier to digest when stewed.

7.3 The digestive system varies between animals

In this topic, you will learn that:

- herbivores are organisms that eat plant material.
- carnivores are organisms that eat meat.
- omnivores, including us, eat a variety of foods.
- the structure of the digestive system can be used to predict the type of food an animal eats.

Teeth tell a story

Before the invention of knives and forks, we used to tear our food apart with our fingers and teeth. Each type of tooth has a specialised function. Incisors have a sharp knifelike or wedge structure, and animals such as rats and mice use their incisors to cut their way through food. Canine teeth are pointed and are useful in ripping lumps of meat apart. This is why many meat eaters (carnivores) have large canine teeth. Molars are flatter and are especially good at grinding the plant food of herbivores into small pieces so that it can be digested more effectively by enzymes.

Palaeontologists are scientists who study fossils, including the skulls and teeth of extinct animals. Palaeontologists use the teeth to predict what the fossilised animal ate when it was alive.

Figure 1 This fossil has a lot of molars and a few incisors. This suggests that it belonged to a herbivore.

Herbivore hindgut

Some plants, such as sugar cane, have a ready supply of the sugar that animals need for energy. Other plants, such as potatoes, contain starch that our enzymes can break up for nutrients. Some parts of plants are very difficult to digest – chemically or physically.

The outside of a plant cell is surrounded by a cell wall made of cellulose. Few animals have the enzyme (cellulase) that can break up this solid nutrient. Instead they rely on good natural flora bacteria to break it up for them. These bacteria live in the **caecum**, a dead-end pouch where food is stored until the bacteria can digest it. In many animals the caecum is found between the small intestine and the large intestine. This is a problem for the animal as it means the plant matter is digested after it passes through the place where the nutrients can be absorbed, in the small intestine. This means many of the good nutrients end up in the faeces. Some animals, such as possums, rabbits, rodents and termites, eat their own faeces to get the extra nutrients that may have been missed the first time through.

caecum
a small dead-end pouch that connects the small and large intestines

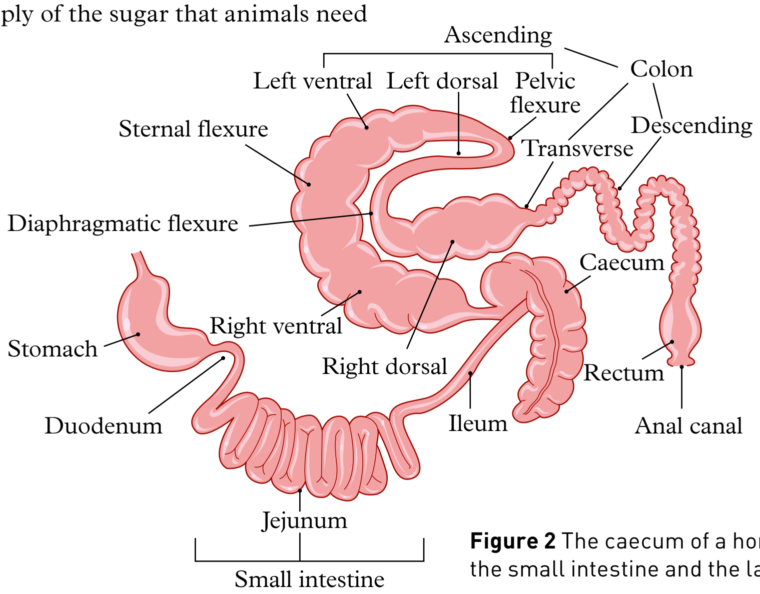


Figure 2 The caecum of a horse is found between the small intestine and the large intestine.

Ruminants

Ruminants are animals with hooves that have four chambers in their stomachs. A cow is an example of a ruminant. When the cow first swallows its food, the grass goes to the first stomach, which is called the **rumen**. This allows the grass to mix with different types of bacteria that can break up the cellulose in the plant's cell wall. The cow regurgitates the grass by bringing it back into the mouth to chew it over and over again to help the bacteria break down the nutrients. The second stomach (the **reticulum**) is involved in trapping any unwanted things the cow might have swallowed, such as rocks or wire. The third stomach (the **omasum**) has many leaf-like folds that filter the fine particles and water into the fourth stomach (the **abomasum**). It is this last section that contains the acid and enzymes, just like a human stomach.

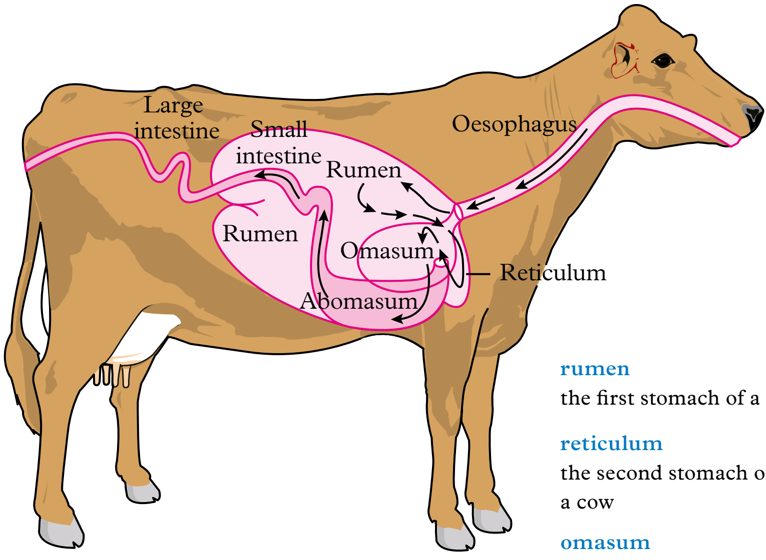


Figure 3 The four stomachs of a cow allow it to digest grass.

rumen	the first stomach of a cow
reticulum	the second stomach of a cow
omasum	the third stomach of a cow
abomasum	the fourth stomach of a cow

7.3 Check your learning

Remember and understand

1 **Describe** why some animals will eat their own faeces.

2 **Describe** two ways the digestive system can be different in animals.

Apply and analyse

3 **Explain** the function of each of the four stomachs found in a cow.

4 **Examine** the images in Figure 4 of the digestive systems of a carnivore, a herbivore and an omnivore. Correctly label each digestive system according to the animal's diet. Provide evidence from the diagrams to support each of your answers.

5 **Identify** the possible diet of the fossils in Figure 5. Provide evidence from the photographs to support each of your answers.

Evaluate and create

6 **Investigate** the digestive system of an animal of your choice. **Compare** your selected digestive system to the digestive system of humans. **Explain** how the structure of your animal's digestive system allows it to digest the food it eats.

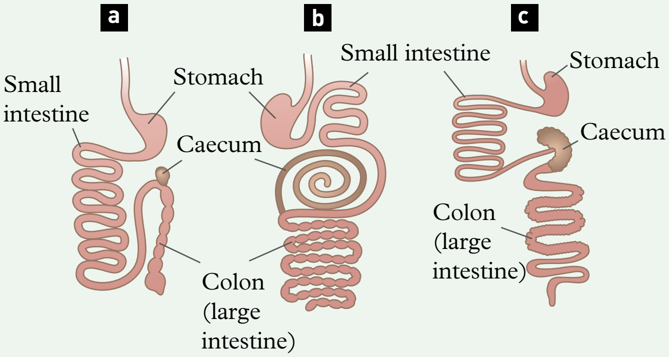


Figure 4 Different animals have different digestive systems (**a**, **b** and **c**) to support the digestion of their food.

Figure 5 Photographs of fossils

Figure 6 The teeth on this dinosaur show it was a carnivore.

//SCIENCE AS
A HUMAN ENDEAVOUR//

7.4 Things sometimes go wrong in the digestive system

Stomach ulcers

For many years ulcers (small open sores) in the stomach lining were thought to be caused by too much rich, spicy food and stress. Patients would come to hospital in a lot of pain from the stomach acid burning the other tissues around the ulcer. Because it was thought no bacteria could survive in the stomach's acid environment, no one considered that bacteria could be the cause of the ulcers.

ulcer	an open sore on the inside or the outside of the body
gallstone	a hard substance or stone that is produced by the gall bladder
ultrasound	a way that sound can be used to identify tissue or to shatter stones
gluten intolerant	unable to digest gluten
diarrhoea	watery faeces

Two Australian scientists, Barry Marshall and Robin Warren, noticed that every patient who presented with symptoms of a stomach ulcer also had the bacterium *Helicobacter pylori* present in their stomach. In the early 1980s they did a series of experiments to show that the spiral-shaped bacteria caused damage to the cells lining the stomach, forming an ulcer. These bacteria can be killed by antibiotics. In 2005, Marshall and Warren were awarded the Nobel Prize for medicine (the highest prize in science).

Figure 2 Robin Warren (left) and Barry Marshall (right)

Gallstones

The gall bladder is a small pouch-like structure that stores the bile from the liver. Bile contains many things, including a detergent-like substance that helps to physically break up the fat that leaves the stomach in the chyme. Occasionally, parts of the bile harden into a small gallstone that stops the bile leaving the gall bladder. The amount of bile in the pouch increases, causing the gall bladder to swell up. This causes severe stomach pains. If the stone cannot be shattered by ultrasound, or removed by surgery, the gall bladder may have to be removed. This means the person will have difficulty digesting fatty foods because of the lack of bile to break up the fats.

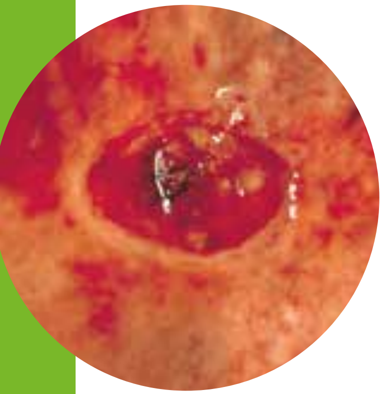


Figure 1 A stomach ulcer

Gluten intolerance

Gluten is a small molecule found in many cereals and grains. Our body uses enzymes to chemically digest the gluten so that we can use the nutrients it contains. Some people do not have this enzyme. This means they cannot digest the gluten and that they are gluten intolerant. It can cause a range of different symptoms, from blockages of the intestines to diarrhoea (watery faeces). Gluten intolerance is different to gluten allergies. If a person is allergic to gluten, their body's immune system fights against the gluten. This can affect their whole body, not just their faeces.

Figure 3 Gallstones

Constipation

Sometimes the large intestine becomes blocked. This can be caused by a poor diet (not enough fruit and vegetables) or by an infection. It usually starts with a small blockage, but as more food moves down the digestive system, it gets caught behind the blockage and gradually fills the large intestine. This causes pain and discomfort. Sometimes medication is needed to help the large intestine move the blockage. If it is not treated, the person may die.

Figure 4 A number of grains contain gluten.

Figure 5 Constipation may cause pain and discomfort.

7.4 Develop your abilities

Planning an infographic

Presenting data to an audience can take many forms. An increasingly common way to present important information is an infographic. Infographics are visual ways to present information so that the viewer can easily see what is important. This can be through the use of graphs, pictures and important figures. Many doctors' waiting rooms have infographics to provide the patients with information about possible diseases.

Select one of the complications of the digestive system in this topic and plan an infographic that will pass the important information on to an audience.

1. **Consider** why you are making the infographic. Is it to pass on information, or to get people to change their habits?
2. **Identify** the key information about the disease and how it affects the digestive system. For example, what are the symptoms and how are people affected?
3. **Describe** how the change in the digestive system causes the symptoms.
4. **Identify** what people who have the symptoms should do. Should they look out for symptoms, change their diet or see a doctor?
5. Draw a picture that represents what is happening in the digestive system. **Consider** how much information needs to be passed on to the person reading the infographic. Try to keep the diagram simple.
6. Infographics use short phrases or sentences to pass on the key information. **Decide** the important information that you want people to remember and write it in short phrases or sentences. Carefully **consider** which words to use so that your audience will know what is important. Have you made the reason for making the infographic clear?

Figure 6 An infographic of heart attack warning signs

7.5 The respiratory system exchanges gases

In this topic, you will learn that:

- the respiratory system is the body system responsible for breathing.
- air is inhaled down the trachea, the bronchi and the bronchioles into the alveolar sacs and eventually into our blood.
- our lungs breathe in oxygen to be used by our cells for energy and breathe out carbon dioxide as waste.

Video 7.5
The respiratory system

Interactive 7.5
The respiratory system

cellular respiration
the chemical reaction between glucose and oxygen to produce carbon dioxide, water and energy

pharynx
the throat; connects the mouth to the oesophagus

epiglottis
a flap of skin above the larynx that controls the passage of food and air, preventing food from entering the windpipe

trachea
the large tube that connects the throat to the bronchi; carries air in and out of the body

Why do we need oxygen?

The respiratory system makes sure that every cell in your body gets the oxygen it needs. Why do cells need oxygen? Most of the food we eat is broken down to glucose, a simple sugar. To release energy from glucose, oxygen is required. This process is called **cellular respiration**. This process is a chemical reaction where glucose and oxygen are converted to carbon dioxide, water and energy. This energy is then used for all the jobs the cell needs to perform, from making and breaking down substances to making new cells.

You can see why people get confused about the difference between breathing and respiration. 'Cellular respiration' is the chemical process that happens in cells and 'breathing' is the inhalation (breathing in) of oxygen and exhalation (breathing out) of carbon dioxide by your lungs and other organs in the respiratory system.

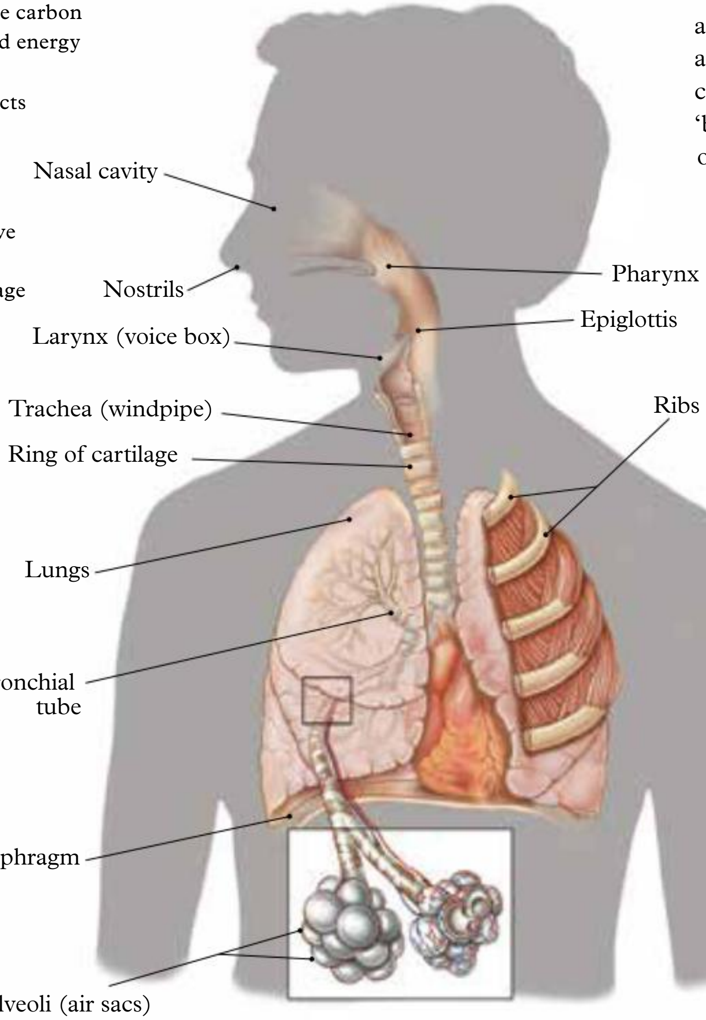


Figure 1 The structure of the respiratory system

Where does the air go?

We breathe air in through our nose and mouth, trapping all the dust and pollens with hairs and wet surfaces as it travels to our throat or **pharynx**. At the bottom of the pharynx is a trapdoor called the **epiglottis** that controls the passage of food and air. Food goes down the oesophagus to the stomach. Air needs to go down the **trachea** to the lungs.

The lungs

There are *two* lungs in our chest. They change size every time we take a breath and they fill with air. The trachea branches into two to carry air into each lung.

CHALLENGE

7.5A: Measure your lung capacity
Go to page **228**.

CHALLENGE

7.5B: Fish dissection
Go to page **228**.

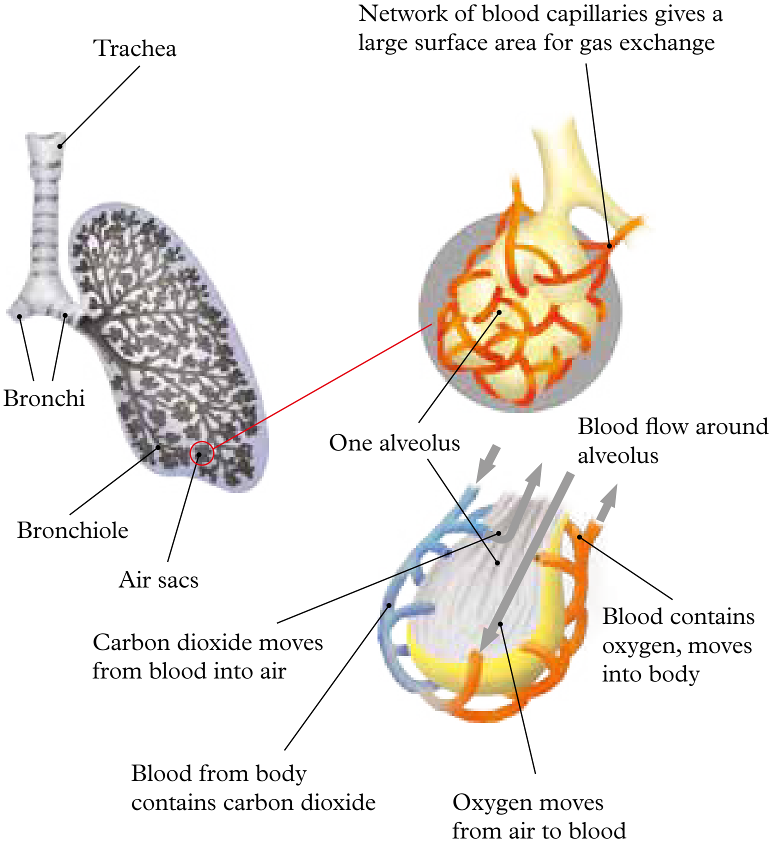


Figure 2 Gas exchange takes place in the alveoli.

These branches are called **bronchi**. The lungs feel spongy to touch because they are home to millions of tiny air sacs called **alveoli**. If these air sacs were unravelled and flattened, the lungs would have a surface area of approximately half the size of a tennis court. Each tiny alveolus (a single alveoli) is covered by a mesh of even smaller blood vessels called capillaries. The lungs are structured to have air sacs surrounded by blood vessels so that air can pass in and out of the blood.

Oxygen moves into the blood, whereas carbon dioxide (the waste product of cellular respiration) moves out of the blood.

The diaphragm

The **diaphragm** is a dome-shaped muscle that is attached to your ribs and moves up and down beneath your lungs. This muscle contracts down and relaxes up. The diaphragm also separates the heart and lungs from the stomach and digestive system. The lungs have no muscle tissue, so they cannot move on their own. Every time you breathe in, the muscles in the diaphragm and between the ribs work together to expand (make your chest larger). As the chest expands, the lungs also expand, pulling air in. When the muscles relax, the chest and lungs become smaller, allowing the air to move out again.

Other respiratory systems

As you learnt in Oxford Science 7, all living organisms exchange gases. The lungs in many animals, including mammals and birds, provide a large surface for oxygen to move into the blood and for carbon dioxide to move out. Other organisms have this gas exchange surface on the outside of their body. The gills of fish have water passing over a large surface area, allowing oxygen in the water to be absorbed into the blood of the fish and carbon dioxide to be removed. This water must constantly be replaced so that the fish have a fresh supply of oxygen.

bronchi
air passages that carry air in and out of the lungs; airways

alveoli
tiny air sacs in the lungs where gas exchange occurs

diaphragm
a dome-shaped muscle attached to the ribs; moves up and down beneath the lungs

7.5 Check your learning

Remember and understand

1. Draw a simple diagram showing how air travels down from the mouth and nose to the alveoli at the end of the branches of the bronchioles.
2. **Define** the term ‘gas exchange’.
3. Gases constantly move in and out of the blood into the lungs. **Identify** the gases that move in and out of the respiratory system.
4. **Describe** the sequence of steps in breathing in and breathing out.
5. **Describe** the role that the epiglottis plays in the respiratory system.

Apply and analyse

6. **Explain** the advantage that the large surface area of the alveoli gives to oxygen needing to pass into the blood.
7. In your own words, **explain** why we need to breathe.

7.6 Things sometimes go wrong in the respiratory system

In this topic, you will learn that:

- small irritations in the upper respiratory system make us cough or sneeze.
- asthma causes the bronchi and bronchioles to become smaller.
- emphysema is caused by broken down alveoli which prevent the oxygen from entering our blood.
- pneumonia is an infection that fills our lungs with fluid and blocks the flow of gases.

Coughing and sneezing

Every time you breathe in, you also take in small particles of dust, pollen and other particles. These particles are trapped by the cells lining our upper airways. Small cilia (hair-like structures) on the surface of the cells trap these particles and push them back to the top of the throat where they are swallowed. Larger particles trigger the diaphragm to contract quickly, making us cough. This pushes up the large particle before it enters the bronchioles.

Sometimes the particles get trapped by the hairs in our nose. This causes a message to go to our brain, which coordinates the muscles in the eyes, chest, stomach and diaphragm, making us sneeze. Some sneezes have been recorded at over 120 km/h.

Figure 1 We cough or sneeze to clear small particles from our airways.

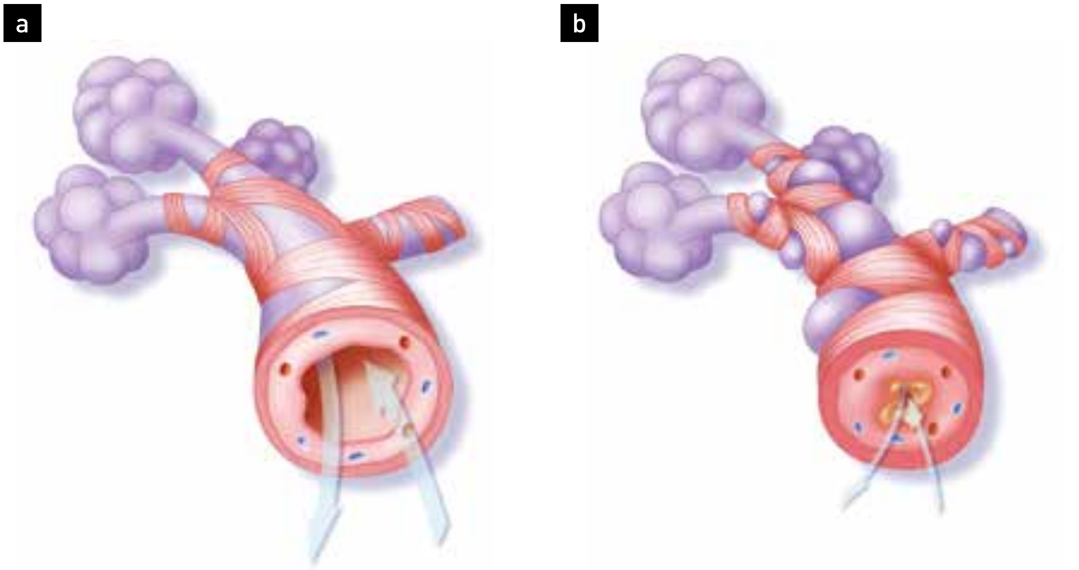


Figure 2 Asthma causes the bronchioles to become narrow: **a** normal airway and **b** asthmatic airway.

Asthma

Asthma is quite common in our population, affecting more than one in ten Australians. Asthma usually starts when something in the environment irritates the airways. This causes the bronchi and bronchioles to narrow, making it harder for air to move into the lungs. When this happens, it is hard to breathe. Asthma attacks can be reversed by drugs, such as Ventolin, that relax and open the airways.

Emphysema

Smoking involves breathing toxic chemicals and tar into your lungs. The tar is like honey, covering the inside of the alveoli and stopping oxygen from moving into the blood. The toxic chemicals in the smoke kill the cells, destroying the alveolar sacs, and travel through the blood to cause trouble all over your body. **Emphysema** is a disease that is caused by the inability of the collapsed alveoli to move air in and out. A person with emphysema struggles to breathe in enough oxygen to walk even 20 m.

Pneumonia

Pneumonia is caused by a bacterial or viral infection in the lungs. The alveoli in the lungs fill up with bacteria, pus and fluid. This prevents air moving into the lungs. Anyone can contract pneumonia, but it tends to be most common in young children and the elderly. A short course of antibiotics (special drugs that kill bacteria) can clear the lungs again, allowing the person to breathe.

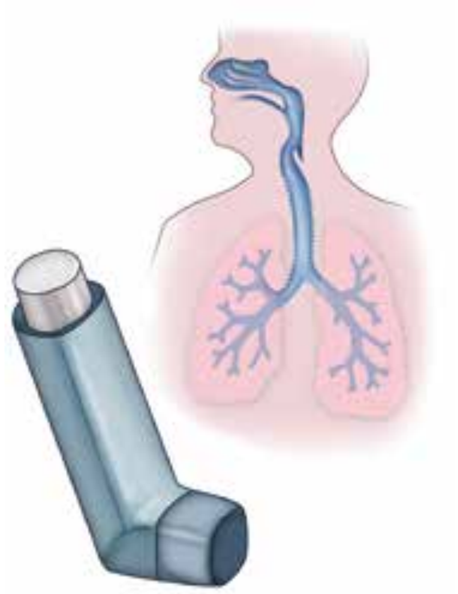


Figure 3 Ventolin is commonly used to control asthma attacks.

asthma
a disease caused by narrowing airways

emphysema
a disease caused by broken down alveoli in the lungs

pneumonia
a disease caused by bacterial or vial growth in the lungs

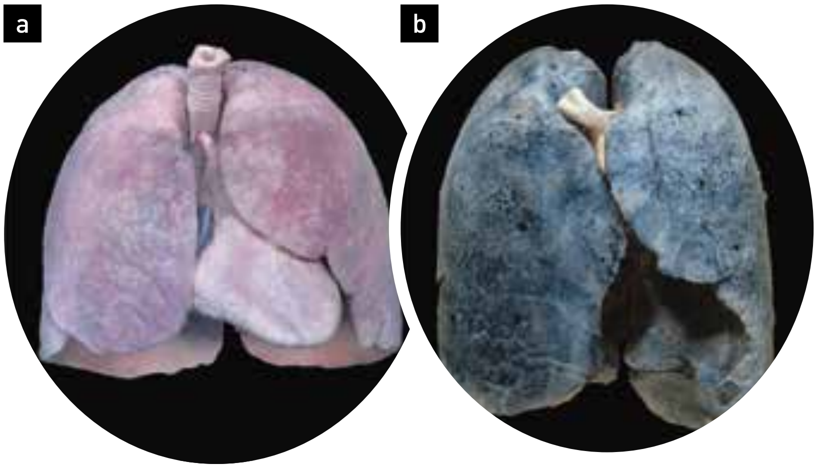


Figure 4 **a** Healthy lungs **b** A smoker's lungs

7.6 Check your learning

Remember and understand

1 **Describe** the cause for each of the following:
  - a a cough
  - b a sneeze.

2 **Describe** what happens in the lungs during an asthma attack.

Apply and analyse

3 **Contrast** the changes in the lung for emphysema and pneumonia.

4 **Explain** why people with pneumonia feel tired all the time.

5 **Explain** why it is physically impossible to keep your eyes open during a sneeze.

6 **Describe** one health risk people take with their lungs and the consequences of this risk.

Figure 5 Ventolin can be purchased at a pharmacy.

7.7 The circulatory system carries substances around the body

In this topic, you will learn that:

- the heart pumps the blood around the body.
- blood contains red blood cells, white blood cells, platelets, plasma, nutrients and waste.
- arteries carry blood away from the heart and veins carry blood back to the heart.
- capillaries are thin-walled blood vessels where nutrients and waste move in and out of the blood.

Video 7.7A
The circulatory system

Video 7.7B
Heart dissection

Interactive 7.7
The circulatory system

The heart

The heart is a large two-part pump about the size of your fist. It is made of four chambers: two **atria** at the top and two **ventricles** at the bottom. The ventricle on the person's right side of the heart pumps blood to the lungs to 'drop off' carbon dioxide and 'pick up' oxygen. This oxygenated blood moves back to the left atrium and on to the left ventricle. The more muscular left ventricle pumps blood out through the **aorta** at the top of the heart and around the body. Valves are like small gates that prevent the blood from moving backwards. They keep the blood moving in the right direction until it gets back to the right atrium of the heart.

Blood is connective tissue containing important cells, liquid and dissolved substances such as nutrients and waste.

> Oxygen is carried by the **red blood cells** from the lungs to all the cells of the body.

atria
the two smaller, upper chambers of the heart

ventricles
the two large lower chambers of the heart

aorta
the major artery that carries oxygenated blood from the heart and divides into smaller arteries around the body

blood
connective tissue that carries oxygen, nutrients and waste around the body

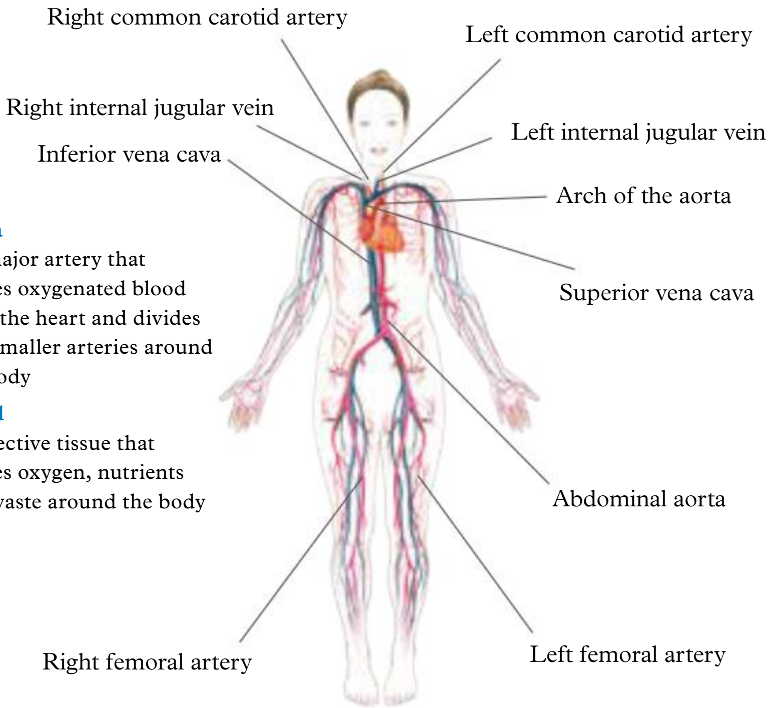


Figure 1 The structure of the circulatory system with key parts labelled

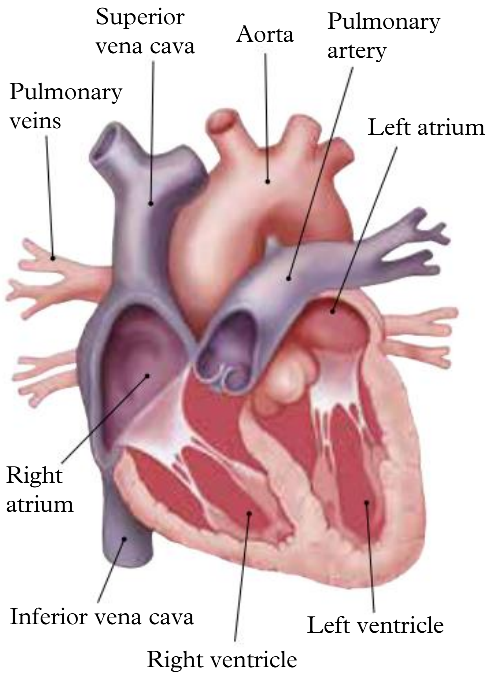


Figure 2 This diagram shows your heart, as well as some of the major blood vessels that travel to and from the heart. The diagram uses a common convention that shows the arteries in red and the veins in blue.

EXPERIMENT

7.7: Heart dissection
Go to page **229**.

Carbon dioxide is dissolved in the plasma (the straw-coloured liquid at the top of centrifuged blood).

- Nutrients and wastes are also dissolved in the plasma for transport to and from cells.
- White blood cells use the blood to travel to places where bacterial cells that cause infection are growing. The white blood cells then kill the bacterial cells.
- Platelets are small cell-like packages that burst when exposed to breaks in the blood vessels. They fill the hole and glue the edges together.

Blood vessels

Blood travels through tubes called blood vessels. Just like our roads, blood vessels have different sizes and structures depending on the amount of blood they need to carry, as well as the speed of the blood and whether it is picking up or dropping off substances.

Arteries are the largest blood vessels. Arteries have thick, muscular walls to cope with high pressure and to help pass the blood along. Arteries carry blood flow away from the heart. The blood is at a higher pressure here because it has just been pumped. Arteries branch into arterioles (smaller arteries).

Capillaries are possibly the most important of the blood vessels. Their walls are only one cell thick to allow substances to easily pass in and out of the blood. Capillaries are the vessels connecting the arteries and veins; they are sometimes referred to as a capillary bed when they are in large numbers surrounding an organ.

Veins carry blood back to the heart to be pumped elsewhere. These vessels are similar in size to the arteries, but only have a small amount of muscle in their walls. To avoid any blood going backwards due to a lack of pressure, veins contain one-way valves.

Other circulatory systems

Not all organisms have large organised circulatory systems. Smaller organisms such as the hydra (1–2 mm long) spend life surrounded by water. It does not have a heart or blood vessels. Instead gases diffuse in an out of the organism's cells. Other nutrients are partially digested in its small tube-like stomach, which has one opening, and absorbed directly into the cells.

Insects have open-ended tubes that take in circulation fluid at the back of the organism and small heart-like pumps that push it forward to the brain. The fluid then leaves the tube and moves freely around the open cavity until it enters the open-ended tube once more. Other organisms, such as the octopus, have three hearts to control the movement of all the substances in their body.

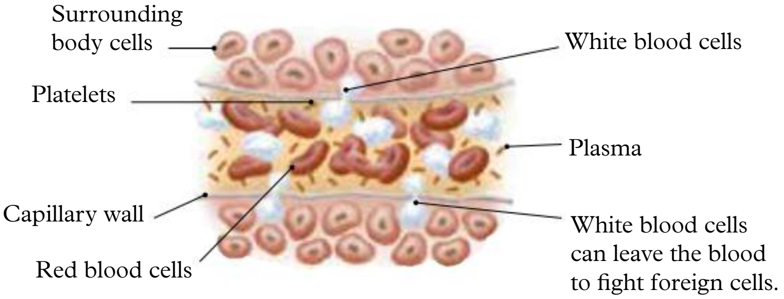


Figure 3 A cross-section of a blood vessel

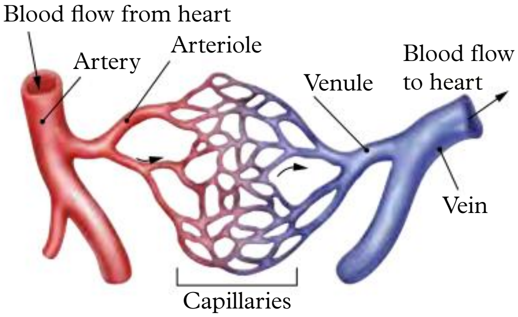


Figure 4 A capillary bed, showing the relationship between arteries, veins and capillaries

red blood cell
cell in the blood that carries oxygen around the body

plasma
a straw-coloured fluid that forms part of the blood

white blood cell
an immune system cell that destroys pathogens

platelets
small disc-like cells in blood that are involved in forming clots

blood vessel
a tube or vessel that carries blood around the body

artery
a thick, muscular-walled blood vessel that carries blood away from the heart under pressure

arterioles
smaller arteries

capillary
a blood vessel with a wall only one cell thick; allows substances to pass into and out of the blood

vein
a thin-walled blood vessel that carries blood back to the heart

7.7 Check your learning

Remember and understand

1 **Describe** the function of red blood cells, white blood cells and platelets.

2 Use diagrams to **describe** how the three blood vessel types differ in their structure and function.

3 Use Figure 4 to **describe** the path a red blood cell takes as it moves through the body from the heart.

4 Rewrite your answer to question 3, adding the names of the veins and the arteries involved.

5 **Identify** the body system that supplies the nutrients that the circulatory system moves around the body.

Apply and analyse

6 Instead of the blood travelling directly from the lungs to the rest of the body, the blood returns to the heart first. **Explain** one advantage of the blood returning to the heart before moving around the body.

7.8

Things sometimes go wrong in the circulatory system

In this topic, you will learn that:

- damaged valves can affect the one-way direction of blood flow.
- atherosclerosis describes the narrowing of the blood vessels as a result of plaque.
- coronary heart disease is caused by blockages in the blood vessels in the heart muscle.
- pericarditis occurs when the pericardium sac surrounding the heart becomes infected.

Interactive 7.8
The excretory system

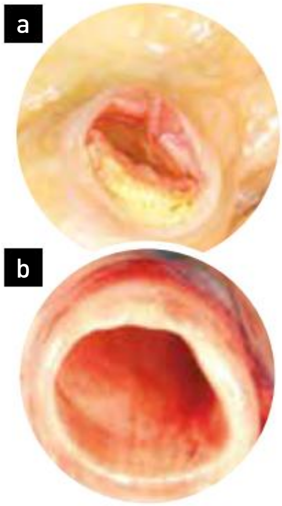


Figure 1 a A blocked artery and **b** an unblocked artery

Valve disease

The heart has a series of valves that prevent the blood from flowing backwards. When the atrium contracts, the ventricle fills with blood. The valve between the atrium and ventricle closes (causing a 'lub' sound), which prevents the blood from flowing backwards. When the ventricle contracts, the blood is forced to flow out of the heart and into the aorta. The valve between the ventricle and the aorta then closes (the dub sound) keeping the blood in the large artery. Now the blood can only enter from the veins again. This is what creates the lub-dub sound you hear when you listen to your heart.

Sometimes these valves become damaged. They may become narrowed from scarring (stenosis), leak (regurgitation or insufficiency) or not close properly (prolapse). This prevents the blood from flowing properly around the body. As a result, less oxygen and fewer nutrients get carried to the cells for energy. This makes the person very tired all the time.

Atherosclerosis

Atherosclerosis is a disease that results from the narrowing of the blood vessels. This narrowing is caused by a build-up of plaque on the inside of the arteries and veins. Plaque consists of fat, cholesterol and other substances normally found in the blood. Layers of plaque are laid down over time, eventually hardening and restricting the blood flow. The symptoms depend on the part of the body affected by the narrowed blood vessel. If the blood vessel is in the heart, then a heart attack will follow.

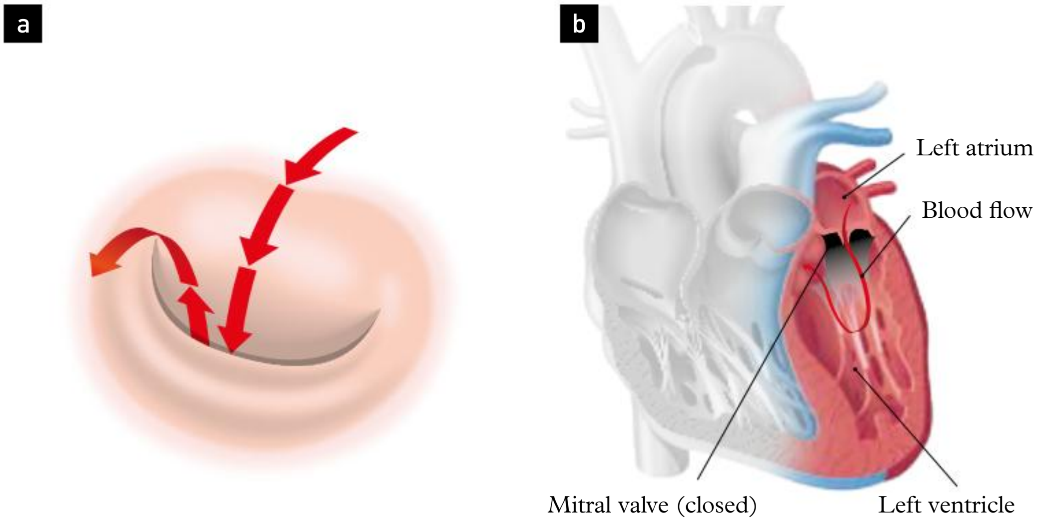


Figure 2 a The heart valve opens to allow blood to flow from the atrium to the ventricle. **b** Closing of the valve prevents the backflow of blood so that it can be pumped effectively around the body.

CHALLENGE
7.8: Modelling blood flow
Go to page **230**.

Coronary heart disease

A heart attack is usually caused by coronary heart disease (CHD), which is basically fatty deposits blocking important blood vessels in the heart. 'Coronary' refers to the heart's own blood vessels. The 'attack' occurs when the vessels become completely blocked or when a bit of the fatty deposit breaks off and travels into the heart. Heart muscle cells may be killed in the process.

So how can you keep your heart healthy? Eating less fatty food is a really good start, but it's not the only thing you can do.

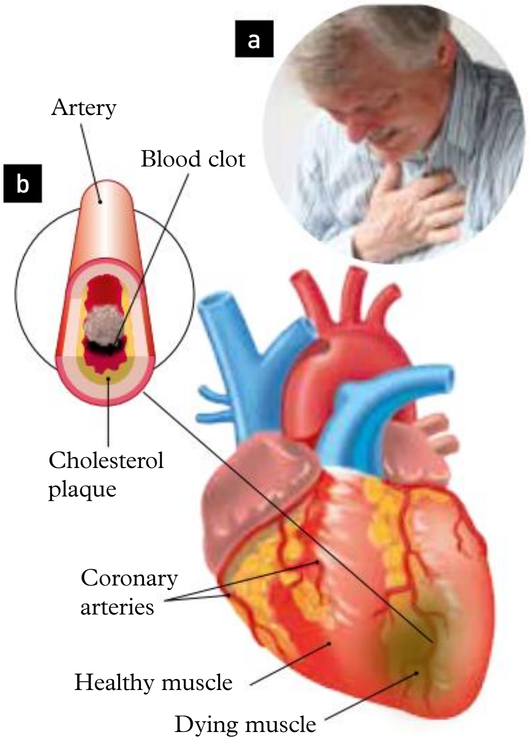


Figure 3 **a** Chest pain is often caused by **b** a blockage in the heart's own blood vessels.

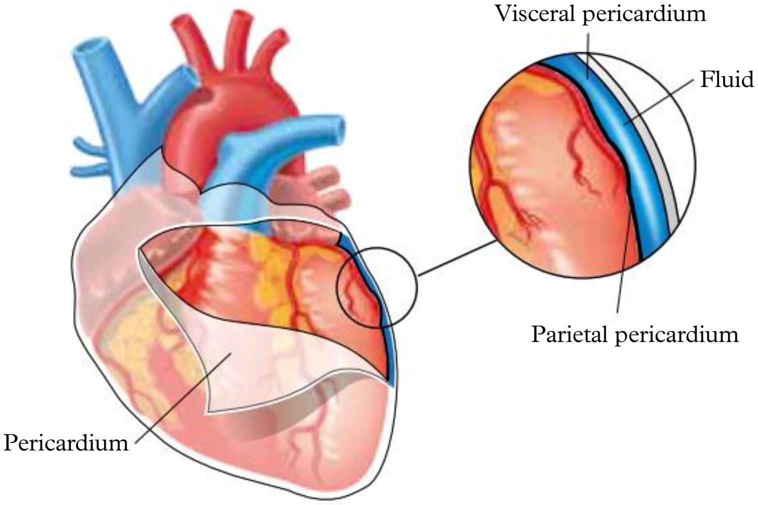


Figure 4 The pericardium reduces friction in a beating heart.

The heart is a muscle and, like all muscles, it needs exercise to keep it strong. Regular exercise is all it needs. In people who are overweight or who smoke cigarettes, the heart needs to work much harder to do the same job. This is actually stressful for your heart. Elite athletes work their bodies very hard, so they need to make sure they have their hearts checked regularly by a doctor.

Pericarditis

The pericardium is the thin sac that surrounds the heart and helps it move easily when it beats. It reduces the friction when the heart beats. Sometimes this thin layer of cells can become infected by bacteria, causing the sac to fill with fluid – a condition known as pericarditis. As a result, the heart cannot beat properly. This restricts the heart from filling properly with blood. Antibiotics are needed to help kill the bacteria so that the heart can start functioning again.

7. 8 Check your learning

Remember and understand

1 **Describe** what causes the lub-dub sound you hear when you listen to your heart.

2 **Describe** the cause of the following valve conditions:

  a stenosis

  b regurgitation or insufficiency

  c prolapse.

3 **Describe** the function of the pericardium sac that surrounds the heart.

4 **Describe** the link between atherosclerosis and coronary heart disease.

5 **Identify** two things you could do to ensure your circulatory system stays healthy.

6 **Describe** why the heart muscle becomes damaged during a heart attack.

7 **Describe** how the function of the pericardium is affected when it fills with fluid during an infection.

Figure 5 Exercise can help keep the heart healthy and strong.

//SCIENCE AS
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7.9

The excretory system removes waste

Our cells and our bodies create a number of waste products. If we are to keep functioning correctly, this waste needs to be removed. The process of removing waste is called excretion. The organs of excretion are the kidneys, liver, lungs and skin. These organs make up the excretory system. Diseased kidneys or livers may need to be replaced by transplantation. This can raise ethical issues.

Interactive 7.9
The skin

metabolism
all the chemical reactions in the body

amino acids
small molecules that make up proteins

ammonia
a chemical waste product (NH_3)

urea
a chemical waste product produced by the body and removed in the urine

nephrons
tiny structures in the kidneys that filter the blood

All of the nutrients that are carried through the body by the circulatory system are used by the cells. These cells undergo a series of chemical reactions that produce chemical products. **Metabolism** is the name given to the chemical reactions that occur in the body. Some of these chemical waste products are toxic and need to be removed (excreted) from the body. Water is important in controlling waste products because it can dilute harmful substances, diluting their effect at the same time. Water is also great for moving substances quickly and is essential for keeping our body temperature just right.

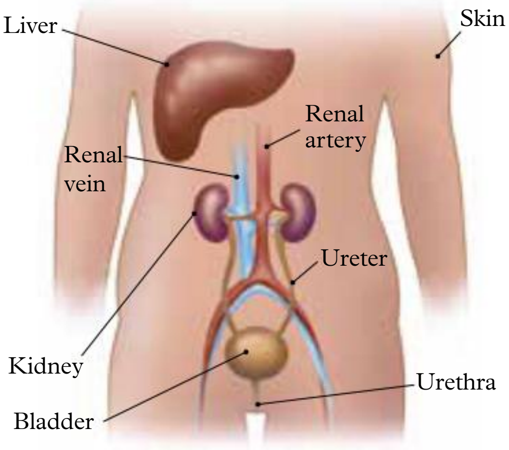

Figure 1 The structure of the excretory system with key parts labelled

The liver

Molecules containing nitrogen are among the most toxic products in your body. When your body digests nitrogen containing proteins, it breaks them down into smaller molecules called **amino acids**. However, it cannot store the amino acids that it doesn't use immediately. Your liver breaks down these amino acids (and many other chemicals) into other less dangerous substances. When the liver breaks down the nitrogen containing amino acids, it produces a very toxic substance called **ammonia**. The liver then uses energy to change the ammonia into a safer substance called **urea**, which is also filtered by the kidneys for removal.

Figure 2 Protein digestion produces toxic ammonia.

The kidneys

You have two kidneys, one on each side of your lower back. They are approximately 10 cm long. Blood carrying waste products enters your kidneys to be filtered by the million tiny structures in the kidney called **nephrons**. At the end of this filtering process there are two main outputs: clean blood and urine.

EXPERIMENT

7.9: Kidney dissection
Go to page **230**.

Figure 3 The salt that you eat helps substances move in and out of cells. However, if there is too much salt in your body, things get out of balance. Your body gets rid of the excess salt by filtering it out through the kidneys.

The skin

The skin is the largest organ in the excretory system. It plays a very important role in releasing waste heat by making you sweat (evaporation from wet skin). Sweating helps you stay healthy by removing waste products such as heat, salts and urea. If you've ever licked your upper lip you will be able to taste the salt in the sweat.

Transplantation

Ethics is the series of rules that define right from wrong. Science often offers possible solutions to problems that challenge people's perceptions of what is right. Organ transplantation is one of these areas.

When the kidney or liver becomes diseased, the types of treatments available are limited. Kidney function can be replaced by dialysis, a 4–6 hour treatment that filters the blood three times a week. Occasionally dialysis is not possible and transplantation is the only option.

There are waiting lists of people who will not survive unless the affected organ (such as the kidneys or liver) is replaced. This list is not determined by race, religion, gender, social status, disability or age. It depends on how well the donor organ matches the recipient, how long the person has been waiting for a transplant, how urgent the transplant is, and whether the organ can be made available to the person in time.

Most commonly, organs are donated by patients who are brain dead. This means their brain is no longer able to keep their heart and lungs functioning. Often the donor had decided to offer their organs before they became ill; however, the family of the donor must also give their permission for the organs to be removed. This is where the ethical issues arise.

7.9 Develop your abilities

Ethical issues of organ transplantation

The waiting list for organ transplantation can sometimes be very long. There are never enough donated organs for everyone on the list. **Consider** the following ethical issue raised by organ transplantation and answer the questions. At each step, justify your answer.

A 15-year-old donor wants to donate one of their two kidneys to a sick school friend. The family of the potential donor does not want their son or daughter to put themselves at risk by donating the kidney.

1 **Explain** why the potential donor may want to donate their kidney.

To donate a kidney, the potential donor must undergo an operation where the kidney is removed through a cut in their side abdominal muscles, which can affect the way they move for several weeks.

2 **Describe** how your life could be affected if you were the potential donor.

3 **Explain** why the family of the potential donor may not want their son/daughter to donate a kidney.

The recipient of the donated organ wants to give a gift to the potential donor.

4 **Explain** why this could be described as selling the organ.

5 **Evaluate** whether the potential donor should give their kidney to their friend by considering how each person (the potential donor and their family and the recipient and their family) would be affected by:

   a the kidney being donated

   b the kidney not being donated.

   Also **decide** which of these reasons is the most important.

Figure 4 When kidneys are unable to clean the blood, patients need to spend 6 hours a day three times a week in dialysis.

CHALLENGE

7.10A: Locating the stomata of a leaf
Go to page **231**.

CHALLENGE

7.10B: Locating the xylem and phloem in a stem
Go to page **231**.

7.10 Plants have tissues and organs

In this topic, you will learn that:

- plants are multicellular organisms that have specialised organs to help move water and nutrients around the body.
- roots use osmosis to absorb water from the soil.
- stems transport the water and nutrients around the plant.
- leaves exchange gases and produce the sugars needed for energy.

roots	a plant organ involved in absorbing nutrients and water
xylem	the tissue in plants that carries water from the roots to the rest of the plant
transpiration	the process of water evaporating from plant leaves; causes water to move up through the plant from the roots
phloem	the vascular tissue in plant stems that carries sugars around the plant
osmosis	the movement of water through a selective membrane from an area of low 'salt' concentration to an area of high 'salt' concentration; occurs in root cells
stem	an organ that transports materials around the plant
vascular bundle	a group of tubes in plant stems that carry water and nutrients around the plant

Roots

The **roots** of a plant are an organ that helps to anchor a plant to the soil and help it absorb nutrients and water. Most root cells have a series of small hairs to increase the amount of surface area that can take in the water. First, the roots take mineral salts from the soil and store them in their cells. This makes the inside of the roots more 'salty' than the soil. Water molecules are attracted to the mineral salts in the root cells. As a result, water moves through the root cell membrane and into the plant. This process is called **osmosis**.

Stem

The **stem** of a plant is the organ responsible for the transport of water and nutrients between the leaves and roots. There are two main structures in the **vascular bundle** of the stem.

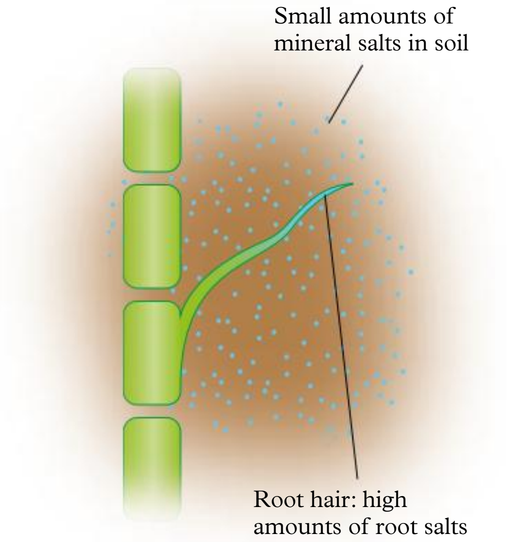

Figure 1 Water moves into the root hair by osmosis.

The **xylem** (*zi-lem*) is a straw-like structure that moves the water from the roots to the top of the plant. Water molecules like to stick together; you can see this in the way a drop of water forms a spherical shape. When water evaporates from the leaves at the top of a plant (**transpiration**), other water molecules move up to replace it. This can pull water molecules from the roots to the top of a 10 m tree.

The **phloem** (*flo-em*) is another network of cells in the plant stem, which transports the glucose produced in the leaves to other parts of the plant. These sugars are needed for all cells in the plant to produce the energy they need to stay alive.

Leaves

The leaves of a plant are involved in exchanging gases. In sunlight, a plant needs carbon dioxide to produce the sugars it needs for energy. The carbon dioxide moves in and out of cells through a small opening called a stoma (plural stomata). A plant stoma has two specialised guard cells

Figure 2 Autumn leaves come in a range of colours.

CHALLENGE

7.10C: Modelling root cells
Go to page **232**.

EXPERIMENT

7.10D: Factors that affect transpiration
Go to page **232**.

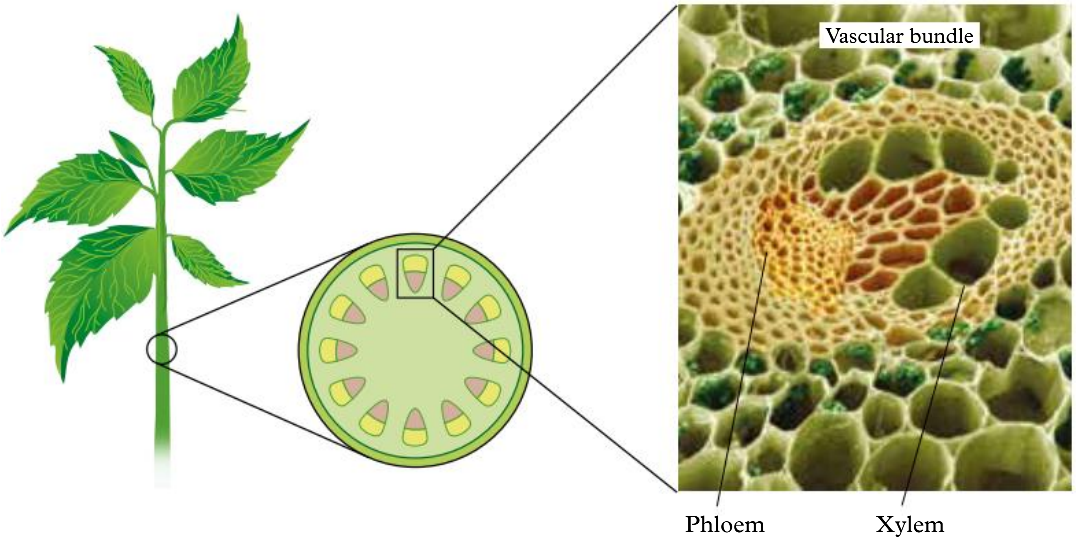

Figure 3 The structure of the stem of a plant

chlorophyll
a green pigment in chloroplasts that absorbs solar energy, which is used by plants in photosynthesis

that can grow longer, forcing a hole to appear between them. This allows air to move in and out. When it is too hot, the plant loses more water than the roots can replace. This causes the guard cells to become smaller, closing the pores in the plant's stomata.

When the sun is shining, the leaves convert the water from the roots and the carbon dioxide from the stomata into glucose (sugar) and oxygen in a process called photosynthesis. Photosynthesis cannot happen without the help of **chlorophyll**. This is the reason most leaves are green.

During autumn, some leaves lose their green chlorophyll. This allows the other colours present in the leaves (reds, oranges and yellows) to appear.

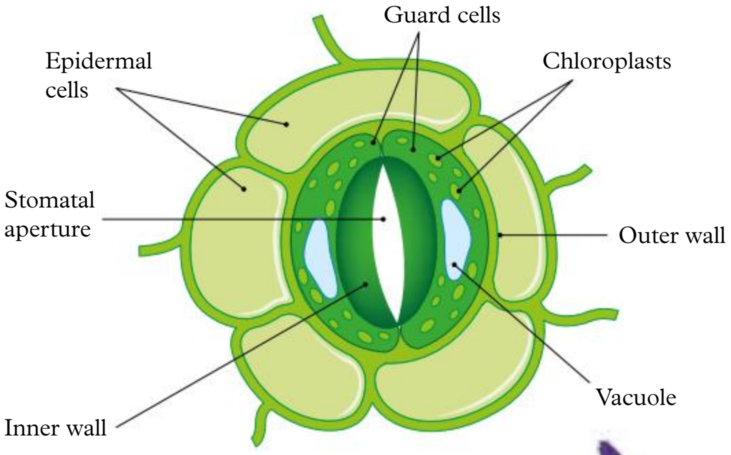

Figure 4 The structure of a plant stoma

7.10 Check your learning

Remember and understand

1 **Name** three organs found in most plants and describe their function (what they do).

2 **Define** the term 'osmosis'.

Apply and analyse

3 **Contrast** xylem and phloem.

4 **Explain** why leaves become red and yellow in autumn.

5 **Identify** the system in humans that provides the same function as a plant stem.

6 Some florists sell blue orchids that are artificially coloured by putting white orchids in blue water. Use your knowledge of plant systems to **explain** how these orchids may have become blue.

Figure 5 Artificially coloured orchids

REVIEW 7

Multiple choice questions

1 **Identify** which body system removes wastes.
- A respiratory system
- B circulatory system
- C digestive system
- D excretory system

2 **Identify** where photosynthesis occurs in a plant.
- A leaf
- B stem
- C root
- D xylem

3 **Identify** the disease that is caused by a build-up of plaque.
- A pneumonia
- B valve disease
- C atherosclerosis
- D asthma

Short answer questions

Remember and understand

4 **Describe** what Leonardo da Vinci did to become famous.

5 **Describe** a possible motivation for the earliest studies of the human body.

6 **Identify** four things that the circulatory system transports around your body.

Figure 1 The respiratory system and circulatory system must work together to supply oxygen to the muscles.

7 **Identify** the gaseous waste product removed by the lungs.

8 **Describe** how the respiratory system and circulatory system work together.

9 **Contrast** 'cellular respiration' and 'breathing'.

10 **Identify** where chemical digestion occurs in the body.

11 **Identify** where peristalsis occurs in the body. **Explain** how it causes food to move.

12 Plants do not have a digestive system. **Identify** which organ helps the plant supply all its energy needs.

13 **Describe** the function of each of the four types of tissue.

14 **Describe** what is meant by 'an ethical issue'.

Apply and analyse

15 **Contrast** 'organ' and 'system'.

Figure 2 Each system in the human body is made up of organs that must work together.

16 **Describe** how the human digestive system can 'feed' all the other systems.

17 **Describe** why muscles need more blood during exercise.

18 **Explain** why you would not expect to find chloroplasts in the roots of a plant.

19 Some people have had the valves in their heart replaced with prosthetic valves, either made from synthetic materials or transplanted directly from a pig or cow heart. **Explain** why it is important that the valves in a heart are functioning properly.

Evaluate

20 Sweating is often considered to be a bad thing. **Evaluate** this statement (by describing why people sweat, what is in the sweat and what would happen if a person was unable to sweat, and then deciding if the statement is correct).

21 Humans have a mix of molars and incisors, whereas canines (dogs) have more incisors. **Compare** the differences in diet between dogs and humans, using the types of teeth each has to support your comparison.

22 Mangrove trees get rid of excess waste salt through their leaves. This salt is often seen as white crystals on the underside of the leaves. **Identify** the system that this represents in the plant. **Identify** which organ(s) has the same function in humans.

23 Human dissections sound like grisly work. **Explain** why it was so important that they happened.

Social and ethical thinking

24 There are many diseases that affect the different organs in the body. Sometimes the only treatment available is an organ transplant. Replacement hearts and lungs can only be obtained from critically injured patients who have been certified brain dead. **Discuss** with a partner the advantages and disadvantages of organ donation. **Explain** the reason why you would or would not sign up to be an organ donor. **Explain** why you should let your family know of your decision.

Critical and creative thinking

25 Imagine it is your job to construct a 'user's manual' for one of the systems covered in this chapter. Write a list of ten 'Frequently Asked Questions' (FAQs) to go at the front of the manual. Write an answer to as many of your questions as you can. If you don't know the answer, write down where you could find the answer or who you could ask.

26 Use your understanding of the different systems of the human body to **create** a concept map detailing the connections between the systems. An example has been provided in Figure 3 to help you get started.

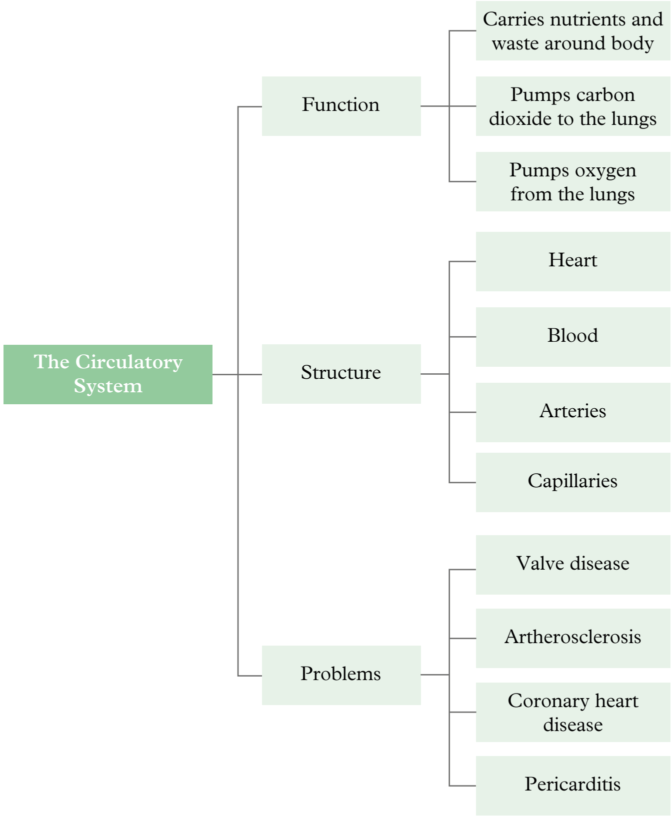

Figure 3 A concept map of the circulatory system

27 Revisit Challenge 7.1, the brown paper body brainstorm that you did at the start of this unit. Look at the body you and your group created. **Evaluate** your own work by writing a short paragraph about how your knowledge of your major body systems has changed after completing this unit. Give yourself a score out of 5 for *then* and a score out of 5 for *now*.

Research

28 Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

» Smoking bans

Many smoking bans, such as bans in workplaces, are related to the issue of second-hand smoke. This refers to how smoke affects people standing near a person who is smoking. Find out some facts about the impacts of second-hand smoke. Argue your position on whether smoking bans should be extended or removed, or whether you think they are fine as they are now.

» Rh factor

Research the Rh factor on blood cells. Describe how the Rh factor is written with blood groups. Identify what percentage of the population is Rh negative and what percentage is Rh positive.

» Getting rid of nitrogen

Animals need to get rid of nitrogen. Some animals produce ammonia, some produce uric acid, some produce urea and others produce guanine. Find out which types of animals produce these different substances to remove nitrogen. Describe the environments where animals produce ammonia. Describe the environments where animals that produce urea live. Describe the advantages for animals of producing the different forms of nitrogenous wastes.

» Omega-3 fatty acids

Describe omega-3 fatty acids. Identify the foods that should be eaten to include omega-3 fatty acids in your diet. Describe how omega-3 fatty acids help reduce heart disease. Describe what other diseases are helped by omega-3 fatty acids.

Reflect

The table below outlines a list of things you should be able to do by the end of Chapter 7 ‘Surviving’. Once you’ve completed the chapter, use the table to reflect on your ability to complete each task.

	I can do this.	I cannot do this yet.
Describe the relationship between cells, tissues, organs and body systems.	☐	☐ Go back to Topic 7.1 ‘Systems are made up of cells, tissues and organs’ Page 130
Define digestion, peristalsis, chyme and villi, and describe the differences between chemical and physical digestion. List the main organs of the digestive system.	☐	☐ Go back to Topic 7.2 ‘The digestive system is made up of organs’ Page 132
Describe why there are differences in the digestive systems of different animals. Relate the structure of organs in the digestive system to their function.	☐	☐ Go back to Topic 7.3 ‘The digestive system varies between animals’ Page 134
Describe some common malfunctions of the digestive system and the diseases or conditions they lead to.	☐	☐ Go back to Topic 7.4 ‘Science as a human endeavour: Things sometimes go wrong in the digestive system’ Page 136
Identify the key organs and structure of the respiratory system including: trachea, bronchi, lungs, pharynx, epiglottis, alveoli and diaphragm. Demonstrate controlled dissection skills.	☐	☐ Go back to Topic 7.5 ‘The respiratory system exchanges gases’ Page 138
Describe the symptoms of asthma, emphysema and pneumonia and explain how ventolin relieves the symptoms of asthma. Provide examples of diseases of the human respiratory system.	☐	☐ Go back to Topic 7.6 ‘Things sometimes go wrong in the respiratory system’ Page 140
List key organs and structures of the circulatory system including: capillaries and veins. Describe the components of blood and their functions, including: red blood cells, plasma, white blood cells and platelets.	☐	☐ Go back to Topic 7.7 ‘The circulatory system carries substances around the body’ Page 142
Describe the main symptoms and causes of some circulatory diseases including: coronary heart disease.	☐	☐ Go back to Topic 7.8 ‘Things sometimes go wrong in the circulatory system’ Page 144
Describe the key organs of the excretory system, including kidneys, skin, bladder and liver. Explain the structure and function of a nephron.	☐	☐ Go back to Topic 7.9 ‘Science as a human endeavour: The excretory system removes waste’ Page 146
List and describe the structure and function of major plant tissues including: stems, leaves, roots, xylem and phloem. Explain the function of stomata in transpiration and photosynthesis.	☐	☐ Go back to Topic 7.10 ‘Plants have tissues and organs’ Page 148

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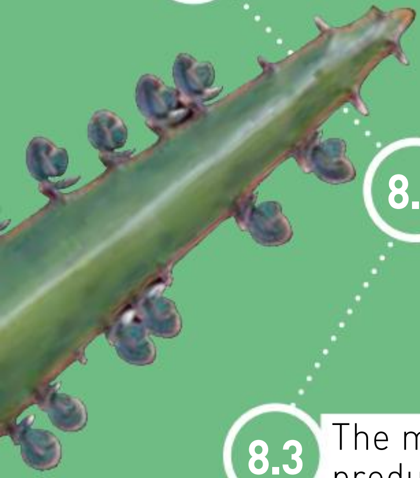
Launch a quiz for your students on key concepts in this chapter.

CHAPTER
8

REPRODUCING

Do all organisms reproduce the same way?



What if?

Dogs and roses

What you need:

A3 paper, pens

What to do:

1 Divide into small groups.
2 Divide the piece of A3 paper into two equal sections.
3 On one half, write down everything you know about how show dogs are bred.
4 On the other half, write down everything you know about how prize roses are grown.

What if?

- » What if a show dog was unable to breed? What would happen to it?
- » What if all rose bushes could grow identical flowers? What other factors could influence the appearance of the rose flower?

8.1 There are different ways of reproducing

In this topic, you will learn that:

- all living things reproduce, leaving new organisms to carry on when others die.
- asexual reproduction involves a single organism making a copy of itself using its own genetic material.
- sexual reproduction involves combining the genetic material from two organisms to produce a new organism.

Figure 1 The queen bee likes parthenogenesis because her unfertilised eggs always become male bees, which means no competition for her crown!

Asexual reproduction

For some organisms, finding a partner is not easy. It takes a lot of energy and time. Some organisms can find partners easily, whereas for those that live alone or are stuck to the one spot, asexual reproduction may be their only chance of continuing the species. Asexual reproduction occurs when an organism makes young copies of itself that only contain its own genetic material.

In asexual reproduction, the offspring will often have exactly the same genetic material (known as DNA) as the parent. If an organism is really suited to an environment (they are able to survive in that temperature with that amount of water and type of food), then their identical 'children' will also be able to survive and grow. However, if the environment changes in any way that becomes unsuitable for the organism, the entire species risks extinction. The simplest version of asexual reproduction is an organism splitting in half to form two new organisms. This is known as **binary fission**.

An amazing asexual reproductive strategy known as **parthenogenesis** involves unfertilised eggs hatching into new organisms. A reticulated python in a zoo, which had been kept isolated from other snakes, managed to lay eggs that produced six daughters. The zookeepers tested the genetic material (DNA) of the baby snakes and found that it was identical to the mother's genetic material. This meant that the baby snakes were tiny identical clones of the mother. Other animals, such as the crown of thorns starfish, are able to form new individuals when they are split into two unequal parts. This is called **fragmentation**.

Fragmentation in plants is called **vegetative reproduction**. Related to the term 'vegetable' (meaning part of a plant), this refers to all non-flower parts of a plant. Vegetative reproduction generally involves a part of the plant breaking off and surviving as a new organism. The plant has no need for spores or seeds – a bit like fragmentation, but with structures that have been grown specifically to be broken off.

Vegetative structures include plantlets, stolons and rhizomes.

Figure 2 Plantlets are tiny plants that grow on either the parent stem, leaf or root.

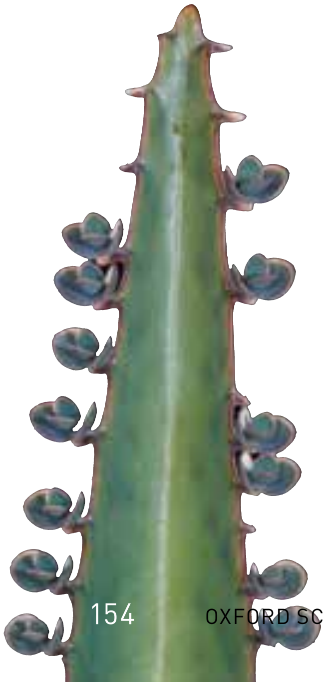


Figure 3 Stolons (runners) are stems running along the ground.

Figure 4 Rhizomes are underground stems.

EXPERIMENT

8.1: Vegetative propagation
Go to page **233**.

Sexual reproduction

The two cells that joined together to make you are called sex cells or **gametes** – an egg from your Mum and sperm from your Dad. Many organisms rely on gametes fusing to make new organisms and this process is referred to as sexual reproduction.

Sexual reproduction produces variations in a population. The **offspring** (babies) are all different from their parents and from each other, having new combinations of features. This variation is really important for the survival of the entire species. It means at least one individual will have the right combination of features to survive if the environment changes. Sometimes a female produces more than one egg. If the two or more eggs are fertilised, then non-identical twins (with different genetic material) can be produced. Occasionally a single fertilised egg can be split into two separate cells. This produces two offspring with identical genetic material – identical twins.

Hermaphrodites

Hermaphrodites are organisms that have both male and female reproductive systems. This means they can reproduce sexually by themselves but, in most cases, it results in organisms that can change sex by 'turning off' one system and 'turning on' the other. This helps to maintain genetic diversity within the species.

Figure 5 Even though nudibranchs are hermaphrodites, they tend to find a partner to mate with. Whichever is fastest at injecting a chemical into the other will get to be the male!

Nature or nurture?

Your genetic material or DNA doesn't control how you cut your hair or what you eat and the same goes for other organisms. Plants cannot control which leaves get eaten by predators and animals cannot control the weather. Scientists have often had lengthy discussions about 'nature versus nurture' – whether DNA is responsible for certain features or whether the features are the result of lifestyle or even upbringing. Your DNA controls your genetic features, such as the colour of your eyes or the length of your nose, whereas the environment (lifestyle, education, etc.) controls everything else and can change regularly. This means genetically identical twins can change slightly (i.e. age faster or slower) if they live in different environments.

Figure 6 Identical twins are only identical according to their DNA at birth.

binary fission
a form of asexual reproduction used by bacteria; the splitting of a parent cell into two equal daughter cells

parthenogenesis
asexual reproduction where a female fertilises her own eggs

fragmentation
asexual reproduction that occurs when a new organism grows from a fragment of the parent

vegetative reproduction
a type of asexual reproduction where part of a plant breaks off, forming a new organism with no need for seeds or spores; similar to fragmentation

gamete
a sex cell; in humans, the sperm and egg cells

offspring
an organism's young, or child

hermaphrodite
an organism that has both male and female reproductive systems

8.1 Check your learning

Remember and understand

1 **Define** the term 'reproduction'.
2 **Identify** the substance that is responsible for most family resemblances.

Apply and analyse

3 **Compare** sexual reproduction and asexual reproduction.
4 **Explain** why variation within a species is considered important.
5 **Describe** one situation where an organism might have difficulty reproducing sexually.
6 **Describe** one situation when parthenogenesis can be useful for organisms that usually reproduce sexually.

Evaluate and create

7 As a class, brainstorm the features of an organism that are genetically controlled (for example, in dog-breeding pugs) compared with those that are influenced by the environment (wild dogs).

8.2

The female reproductive system produces eggs in the ovaries

In this topic, you will learn that:

- the female reproductive system varies between vertebrates depending on the reproductive habits of the species.
- human females have a large uterus, two fallopian tubes and two ovaries.
- each month an ovary produces one ovum during ovulation.
- some animals (rats and rabbits) have a uterus large enough for multiple foetuses.
- amphibians lay their eggs in water.

ovum
the reproductive egg

ovary
the female organ that produces eggs

oestrogen
a reproductive hormone in females

ovulation
the part of the menstrual cycle when an egg is released from the ovary

fallopian tubes
tubes that connect the ovaries to the uterus

uterus
an organ in the female reproductive system; where the foetus develops

endometrium
the lining of the uterus

zygote
a fertilised egg

foetus
an unborn animal or human after the embryo stage; in humans this is after 8 weeks of development

cervix
the narrow neck connecting the uterus and the vagina

vagina
a female reproductive organ; a muscular tube connecting the outside of the female body to the cervix

Human reproduction

In humans, girls are born with hundreds of thousands of eggs or ova (singular '**ovum**') partially formed in their **ovaries**. After puberty, every month a chemical messenger from the brain sends a message to the ovaries to secrete the chemical messenger **oestrogen**, which causes one egg to mature and be released. This process is called **ovulation**.

The egg travels down the **fallopian tubes** to the **uterus**. If sperm are present in the fallopian tubes, then the egg may become fertilised. In the 3–5 days it takes for the egg to travel the fallopian tubes, the lining of the uterus (the **endometrium**) becomes thicker. This is to provide a safe place for the fertilised egg, or **zygote**, to grow into a **foetus**.

If the egg is not fertilised, then the endometrial lining will break down and, 2 weeks after ovulation, will pass through the **cervix** and **vagina** as a period. This monthly cycle is called **menstruation**.

Menstruation usually first occurs in females between 8 and 16 years of age. It can take up to 2 years for menstruation to become a regular cycle. The average length of the cycle is 28 days, but it can vary from 23 to 35 days.

If the egg is fertilised in the first three days after ovulation and develops into a zygote, then it attaches to the thick endometrial layer. A special organ called the **placenta** forms between the foetus and the uterus. The placenta allows oxygen and nutrients to pass from the mother to the developing foetus. The length of time between fertilisation and birth is called **gestation** (or pregnancy). In humans this takes 9 months.

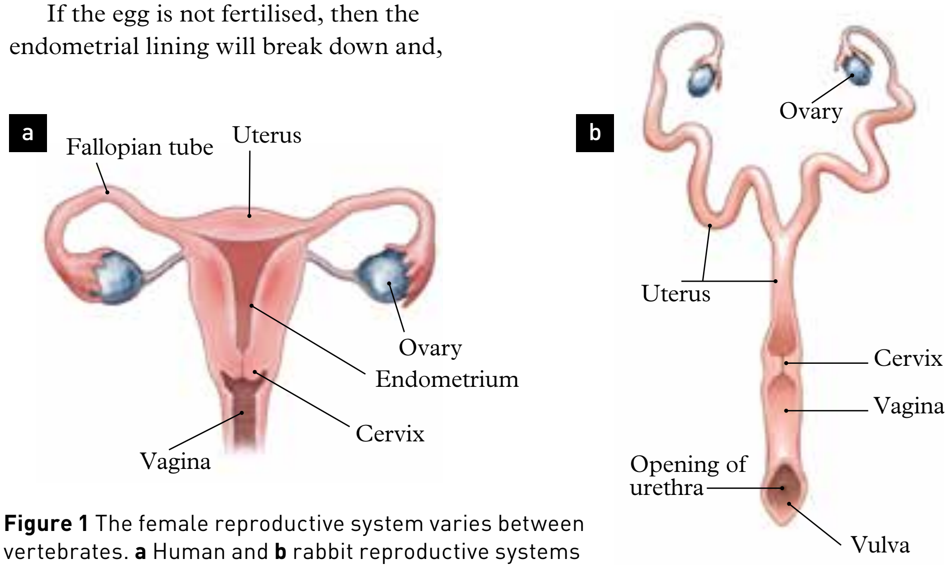


Figure 1 The female reproductive system varies between vertebrates. **a** Human and **b** rabbit reproductive systems

Figure 2 A human foetus

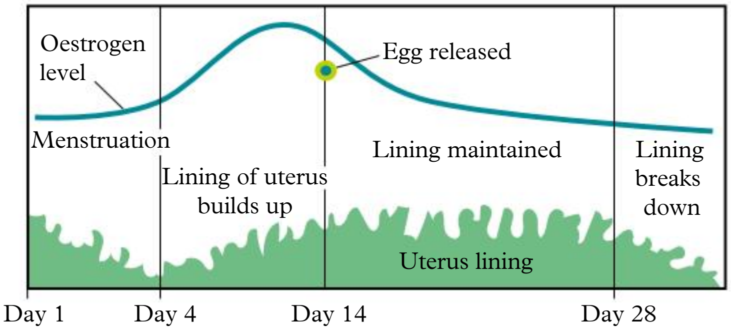


Figure 3 During the average 28-day menstrual cycle, ovulation occurs at day 14.

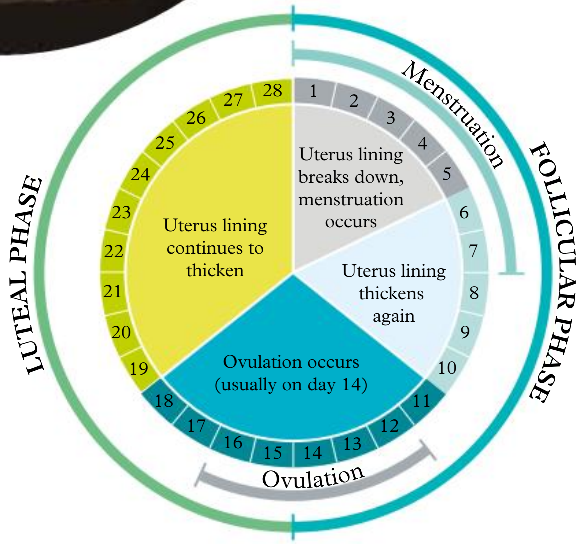


Figure 4 The menstrual cycle begins on the first day of a period.

Giving birth

Human mothers go through three stages when giving birth. The first stage involves the muscular walls of the uterus contracting, gently squeezing the baby down against the cervix. This causes the cervix to flatten and start dilating (opening). The cervix must open 10 cm before the baby's head can move through the vagina. This is the second stage of birth. When born, the baby is still attached to the placenta, which is inside the mother, via the umbilical cord. When the umbilical cord is cut, it will form the belly button on the baby. The third and final stage of birth is the delivery of the placenta. This is important to prevent infections from developing in the uterus.

menstruation
also know as a period; the process of the endometrial lining of the uterus breaking down and leaving the vagina

placenta
the organ that connects the developing foetus to its mother

gestation
the length of time between fertilisation and birth

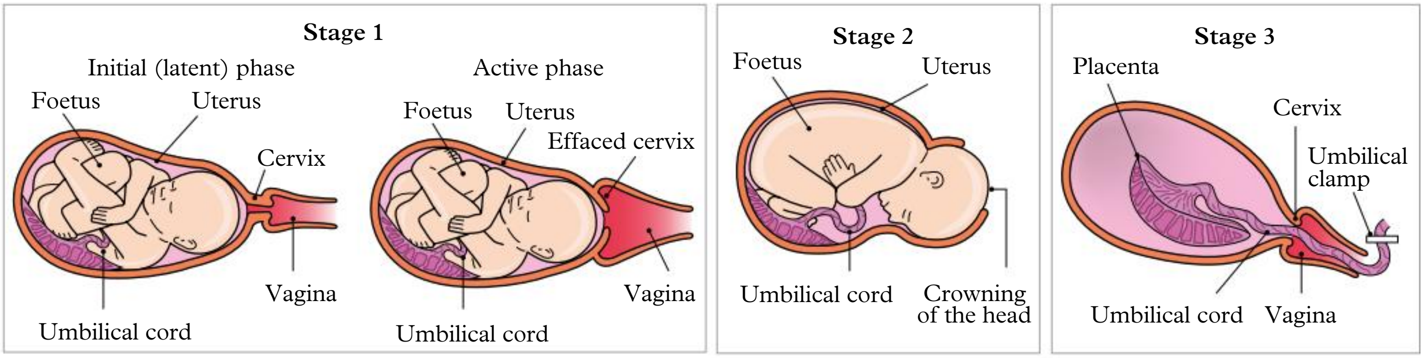


Figure 5 The three stages of childbirth

8.2 Check your learning

Remember and understand

1 **Identify** a chemical messenger in human females.

2 **Identify** where in the reproductive system the ovum becomes fertilised in humans.

3 **Define** the term 'menstruation'.

4 **Describe** how often menstruation usually occurs.

5 **Describe** the three stages of giving birth.

6 **Identify** the days (1, 2, 3 …) in the average cycle.

- **a** The first day of a period.
- **b** The usual day of ovulation.
- **c** When the ovum can be fertilised.

Apply and analyse

7 A student said that a baby girl already had all her eggs intact when she was born. **Evaluate** this claim (by describing where all the eggs/ova are located, describing when this organ is fully formed and deciding whether the statement is correct).

8.3 The male reproductive system produces sperm in the testes

In this topic, you will learn that:

- male mammals produce sperm in their testes.
- sperm will mature in the epididymis, travel along the vas deferens where the seminal vesicles provide nutrients before being ejaculated from the penis.

sexually dimorphic	describes species in which the male and female organisms look structurally different
testis	the male reproductive organ that produces sperm (plural: testes)
testosterone	a male hormone involved in the reproductive system
scrotum	a sac-like structure that contains the testes
epididymis	a coiled tube behind the testes that carries sperm to the vas deferens
vas deferens	the tube through which sperm travel from the epididymis to the prostate
seminal vesicles	a pair of small pouch-like structures that provide a sugary fluid that assists sperm to travel along the vas deferens
prostate gland	a walnut-sized structure surrounding the neck of the male bladder that blocks the flow of urine so sperm can move along the urethra
internal fertilisation	when the sperm fertilises the egg inside the body of an organism

The vast majority of animals reproduce sexually. They are also **sexually dimorphic**, which means that the males look physically different from the females.

Male reproductive organs

In fertilisation, a gamete from the father (sperm) must meet a gamete from the mother (egg or ovum). The sperm is produced in special organs called the **testes**. The testes are also responsible for producing a male chemical messenger called **testosterone**. In most animals, the two testes are kept outside the body in a sack called the **scrotum**. This is to keep the sperm cooler than the 37°C of the rest of the body. If sperm get too hot they will not be able to fertilise an egg properly.

Once sperm are produced in the testes, they move to the **epididymis** to mature. When necessary, the epididymis contracts (squeezes tight), and the sperm is moved into the **vas deferens**. The sperm need energy to be activated. **Seminal vesicles** are small pouch-like structures that provide a sugary fluid that is needed for the sperms' journey along the vas deferens tube to the **prostate gland**. The prostate gland is a walnut-sized structure that blocks the flow of urine so that the sperm can move along the urethra and be ejaculated out through the penis. The function of the penis is to help the sperm reach the eggs. Sperm can survive up to five days after ejaculation.

Fertilisation

Mammals, such as humans, use **internal fertilisation** and the mother is responsible for nurturing the growing foetus in the uterus until it is ready to face the world. Placental mammals, like humans, keep the foetus in the uterus for this period, whereas marsupial foetuses such as those of the koala, crawl into the pouch for the final stages of development.

Monotremes, a very rare group of mammals that consists of the platypus and the echidna, lay leathery eggs.

All mammals suckle their young with highly nutritious milk from the mother to give the young the best start in life.

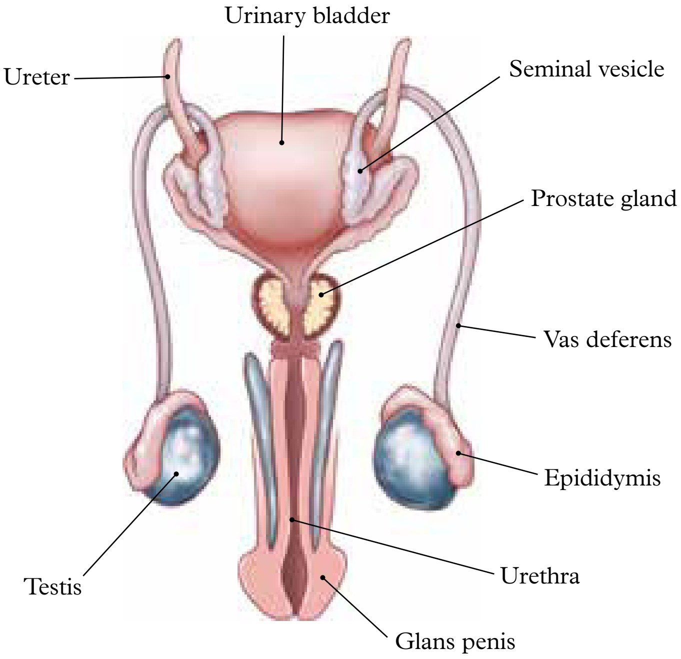


Figure 1 Human male reproductive system

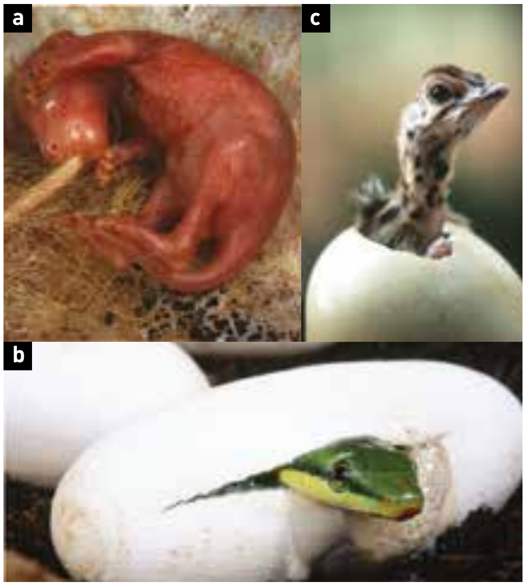


Figure 2 a Marsupial foetuses finish developing in the pouch. **b** Reptile eggs are leathery white. **c** Birds' eggs are hard.

Like monotremes, reptiles and birds lay internally fertilised eggs. Reptile eggs are leathery, whereas bird eggs have a hard shell. The eggs contain all the nutrients the foetus needs to develop fully, which is really important for reptiles because most of them leave their babies to fend for themselves.

Amphibians and fish generally practise **external fertilisation**. This usually involves the female laying the eggs in the water and the male coating them with sperm. Often hundreds of eggs are laid at once so there's a greater chance some will survive – they make a tasty snack for passing predators! Some parents will keep watch to ward off predators.

external fertilisation
when the egg and sperm meet outside the bodies of the parents

Invertebrates making babies

Invertebrates account for approximately 95 per cent of all animals, so it's not surprising that their reproductive strategies vary quite a lot.

Arthropoda, the group that includes insects, spiders and crustaceans, is the largest group of invertebrates.

Terrestrial (land) arthropods generally favour internal fertilisation because of the harsh conditions they often live in. Sometimes the sperm is transferred directly into the female's **oviduct** (similar to the vagina) and sometimes the sperm is packaged for delivery to the female in more complex ways. Most arthropods will then lay their eggs. Insects and crustaceans tend to hatch as larvae. Spiders hatch as miniature adults.

oviduct
the tube through which eggs travel from the ovary

Figure 3 Some fish protect their eggs from predators.

Figure 4 A female fly lays eggs through her oviduct.

8.3 Check your learning

Remember and understand

1 **Define** 'sexual dimorphism' in your own words.

2 **Name** a chemical messenger in males.

3 **Identify** the two vertebrate classes that lay leathery eggs.

Apply and analyse

4 **Explain** why animals that use external fertilisation usually lay a large number of eggs.

5 **Identify** the group of mammals that has the longest gestation. **Explain** why this would be an advantage for the baby.

6 **Explain** why terrestrial invertebrates fertilise their eggs internally rather than externally.

Evaluate and create

7 If an ovum is produced on day 14 of a menstrual cycle, and sperm can survive up to 5 days before fertilisation, **identify** the days of a cycle that a woman can become pregnant.

8 **Create** a story that describes the journey of Mr Sperm from his home in the testes to meet the love of his life, Ms Ovum.

//SCIENCE AS
A HUMAN ENDEAVOUR//

8.4

Things sometimes go wrong in reproduction

There are many situations in which we wish to encourage reproduction. For example, when a human couple are unable to have a baby, technology can intervene. When a species is threatened with extinction, technology can reduce the threat; when certain features or characteristics are favoured, humans step in to influence the outcome; and when reproduction is just not an option, something can be done to prevent it.

Endometriosis

Sometimes the lining of the uterus, the endometrium, starts growing outside the uterus. These cells can grow on the outside of the uterus or spread to other organs, such as the ovaries. Each month these endometrial cells grow, and then break down, just as in the menstrual cycle. This can be very painful; it can cause vomiting or prevent a woman from doing her normal activities. Also, the scarring that results can prevent the eggs from moving down the fallopian tubes. This can make it difficult for pregnancy to occur. Anyone who suffers from endometriosis should see their doctor so that it can be treated.

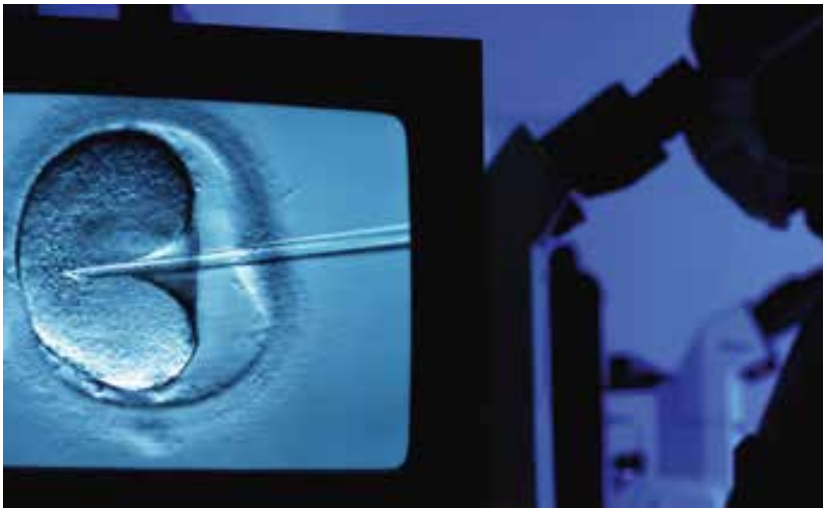


Figure 1 In IVF, eggs are injected with sperm for fertilisation.

Human reproduction

Assisted reproductive technology (ART) is the name given to any procedure that is used to help a couple have a healthy baby. Through in vitro fertilisation (IVF) an egg is fertilised by sperm *in vitro* or ‘in glass’, meaning in a test tube. This is done so that a doctor can carefully watch every step to make sure that the egg gets fertilised and begins dividing as it is supposed to. The tiny embryo can then be transferred back into the mother’s uterus to go through a normal pregnancy.

Unborn babies can be screened for problems. The amniotic fluid that protects the growing foetus can be tested (amniocentesis), as can the cells of the placenta (chorionic villus sampling). The problem with these tests is that they involve inserting a needle into the belly, which may result in an infection or may interfere with the pregnancy, risking more problems than can be diagnosed. Thankfully, many issues can be spotted in an ultrasound – a picture of what is going on inside, complete with heartbeats.

Preserving biodiversity

Humans rely on the diverse range of living things (biodiversity) for food, transport, tourism and even inspiration, so it is really important that we try to stop species becoming extinct.

Many scientists work out in the wild to try to help different organisms, but the most intensive programs are often happening in our zoos and sanctuaries. These are called captive breeding programs.

When an animal is in a zoo, specialists of all types can observe and help the animal to breed. They might try to make the environment ideal by changing the temperature or providing the right nutrients. They can also bring animals together at just the right time, or even try animal IVF.

CHALLENGE **8.4:** Working with the RSPCA
Go to page **233**.

Figure 2 Captive breeding programs are helping to save the bilby.

Contraception and desexing

It may sound silly, but many animals in captivity are on some form of **contraception** to stop them getting pregnant. This may be to control **inbreeding** or simply because there's not enough room or resources for more animals in the facility.

Desexing is a permanent contraceptive strategy that involves either the male or the female having their vas deferens or fallopian tubes 'tied', or blocked, or removed altogether.

Local councils very commonly require animals that are pets to be desexed. Cats, for example, often wander freely during the day and have many opportunities to breed – but who will look after all the kittens? If everyone's cats were free to breed, the neighbourhood would soon be swarming with kittens or wild cats hunting all the local wildlife.

Figure 3 Ultrasounds allow the developing foetus to be seen.

contraception
a way of preventing pregnancy

inbreeding
breeding of animals that are related, increasing the chances of genetic abnormalities appearing

desexing
a method of permanently preventing reproduction

Figure 4 It's not a very happy life for domestic animals without food or shelter.

8.4 Develop your abilities

Analysing and evaluating a zoo

Many people argue that it is inhumane to keep animals in a zoo. They claim that the animals are kept from their normal habitat for the enjoyment of humans. Use critical thinking to decide whether you support your local zoo. To do this, complete the following tasks.

1 **Define** the term 'inhumane'.

2 **Consider** how the animals usually live in their normal habitat. Select one animal as an example.
   a **Research** the plants, temperature and shelter that the animal has in their habitat in the wild.
   b **Research** the types of food that your chosen animal eats.
   c **Research** the usual habits of your chosen animal (i.e. how far they move, what they do each day, whether they live in groups).

3 **Compare** your research to how the animals live in the zoo.

4 **Identify** how endangered your animal is in their usual habitat and if the zoo is involved in any breeding programs. **Describe** the breeding program.

5 **Explain** why you do or do not support your local zoo.

8.5

Plant sexual reproduction produces seeds

In this topic, you will learn that:

- flowers help plants to use sexual reproduction.
- when the male plant gamete lands on the female plant gamete, pollination has occurred.
- plants can self-pollinate or be cross-pollinated by another plant.
- insects or birds can help pollinate plants.

Video 8.5A
Flower dissection

Video 8.5B
Flowering plants

stigma
the male part of a plant, consisting of a filament supporting an anther

carpel
the female reproductive organ of a flower; includes the stigma, style and ovary

anther
the end part of a stamen (male part of a flower); contains pollen

pollination
fertilisation of gametes in plants

self-pollination
when both gametes come from the same plant

cross-pollination
the exchange of pollen and ova between different plants of the same species

Flowers come in all shapes and sizes. Not all of them are attractive and many smell terrible instead of lovely. However, the purpose of a flower is not necessarily to be sweet-smelling and beautiful, but to contain the sexual reproductive organs of the plant and to help fertilisation to occur.

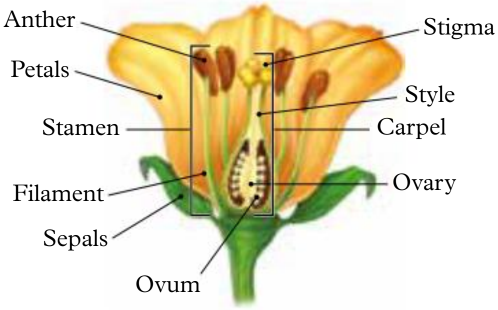


Figure 1 Basic structure of a flower

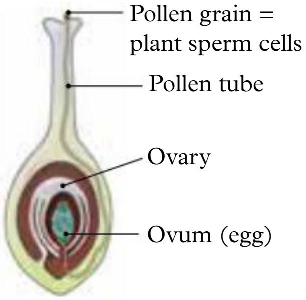


Figure 2 Structure of the carpel with key structures labelled

Pollination

The female gamete, also called an ovum, is located at the base of the **stigma** inside the ovary. All these female parts together are called the **carpel**. For fertilisation to occur, the male gamete needs to find its way from the top of the male structure, the **anther**, to the ovum. This requires **pollination**, the process of pollen attaching to the stigma and 'digging' a pollen tube down to the ovary.

Flowers sometimes need assistance from other organisms (insects, birds or mammals) or the environment (wind or rain) for pollination to occur. **Self-pollination** involves pollen from a flower landing on its own stigma or that of another flower on the same plant. **Cross-pollination** occurs when pollen from a flower lands on the stigma of a flower on a different plant, combining two different sets of genetic material. Just as in animals, the pollen from one

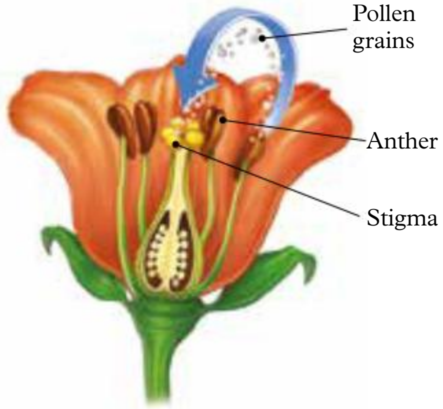


Figure 3 Self-pollination

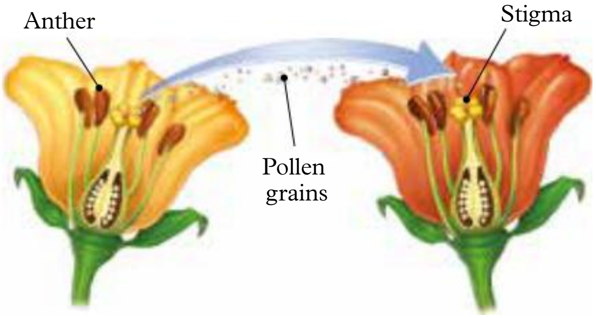


Figure 4 Cross-pollination

EXPERIMENT

8.5: Flower dissection
Go to page **234**.

flower can only fertilise flowers from the same or a similar species.

After fertilisation, the ovary takes on a role similar to that of a bird's egg. It swells to become a fruit, which provides nutrition and protection for the zygotes to grow into embryos inside the seeds. The ovary structure is seen in the structure of the seed-bearing area of the fruit, as shown in Figure 1.

Not all flowers are the same

If a flower smells, it is usually to attract a pollinator – but not all smells are sweet. The flowers of Borneo's Rafflesia plant smell like rotting flesh to attract flies for pollination!

The colour of a flower is also important for attracting pollinators. Birds tend to pollinate bright-coloured flowers, including red, whereas insects may be more attracted to a wide range of colours. Mammals that feed at night will rely on strong scents and not on colour at all.

Figure 5 When in bloom, the Rafflesia smells like rotten meat to attract pollinating flies.

Some flowers have modified structures to suit their pollinators. Birds may damage flowers with their sharp beaks when they drink the nectar, so flowers need to be strong. Insects can be small and need to be forced to brush against pollen, followed by the stigma, so the flower may be full of obstacles or simply a tight fit.

Sexual spores

If you've ever had a good look at a fern you will have noticed that its leaves are usually quite different from the leaves of flowering plants. You will often see brown patches on the underside of fern fronds. These brown patches are specialised cells that make and release **spores** onto the ground. The spores are tiny reproductive structures that have half the genetic material of seeds. They grow into tiny heart-shaped plants called prothalli that are made up of male and female reproductive organs. Male and female gametes are produced and released when it rains – hopefully, to find a match for fertilisation. The little plant then dies, but the fertilised eggs grow into new ferns.

spore
a tiny reproductive structure that, unlike a gamete, does not need to fuse with another cell to form a new organism

Figure 6 Fern sori produce spores for reproduction.

8.5 Check your learning

Remember and understand

1 **Identify** the structure that holds a plant's sexual reproductive systems.

Apply and analyse

2 **Contrast** self-pollination and cross-pollination.

3 **Compare** fertilisation and pollination.

4 **Compare** a spore with a seed.

5 Draw a circular flow diagram using the following terms: flower, pollen, seed, fruit, pollination, fertilisation, ovum, pollen, ovary, stigma and anther.

6 **Explain** why some flowers are large and coloured, and others are tiny and plain.

7 Plants that are successful weeds often use both sexual and asexual reproduction. Mint is common in herb gardens and reproduces with little flowers as well as using vegetative reproduction. **Explain** why it would be difficult to get rid of mint once it has spread through a garden bed.

8.6 Reproduction techniques have an impact on agriculture

In this topic, you will learn that:

- reproductive technologies can be used in agriculture to improve desired characteristics in plants and animals.
- reproductive technologies can have an impact on diversity and increase the risk of inbreeding.

Selective breeding

There are many examples of animals and plants being bred to keep, lose or enhance certain characteristics by people choosing the 'partners'. For example, a cow that is known to produce a lot of milk could be chosen to breed with a bull that is known to produce healthy, strong offspring. This would result in a greater chance of any female offspring being good milk producers and any male offspring being good meat producers.

Occasionally animals have difficulty in breeding. This may be due to location (the animals may be on opposite sides of the country) or their owners wanting to have greater control over the animals they breed with. As a result, sperm banks for animals have been developed. Desired characteristics, such as speed or 'staying power' in racehorses, or facial shape or coat colour in dogs, are described in a catalogue for owners to examine. The desired frozen sperm can be purchased and sent to the owner of the female animal, where it will be used to create offspring with the desired characteristics.

Selective breeding also applies to plants. A type of wheat that is known to survive frost or disease can be deliberately cross-pollinated with a type of wheat that produces high-quality grains; the aim of this is to produce a grain that combines both features.

Loss of diversity

Diversity in plants and animals refers to the variety of genetic material in a single population or species. When a characteristic, such as milk production in cows, is used for selective breeding, any cow that does not produce 'enough' milk is discouraged from breeding. This often means the genetic material from that cow is not passed on to the next generation. Instead, the next generation of calves will only have genetic material from the

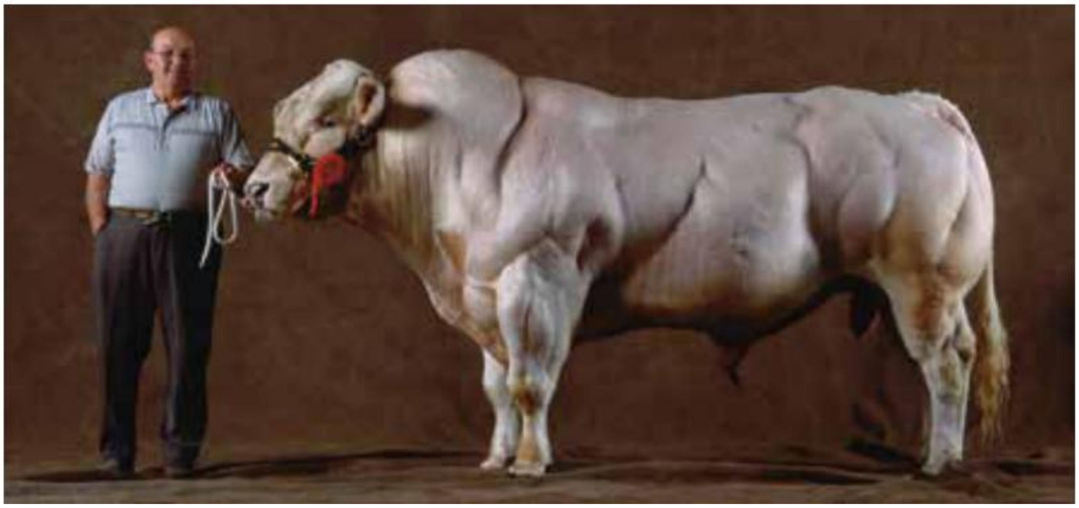


Figure 1 Some people get a little carried away with selective breeding.

few cows that meet the milk production criteria. As a result, most of the cows can be related to each other and there is less variation in the genetic material. Although this does not seem like a problem initially, it puts the whole population at risk of disease. If one plant or animal is at risk of a disease, then the rest of that related population, with the same genetic material, is also vulnerable.

An example of this is the facial tumour in the Tasmanian devil. All Tasmanian devils have very similar genetic material. When one individual devil developed a tumour on its face, it was able to pass it on to another devil that had similar genetics.

Figure 3 The Tasmanian devil facial tumour is caused by the uncontrolled growth of a cancerous cell.

Figure 2 In the mid-1800s, the population of Ireland relied very heavily on potatoes for food. When a fungus infected the potatoes, the lack of genetic diversity meant that all potato crops were wiped out and about 1 million people died of starvation.

Inbreeding

Inbreeding results from animals reproducing with animals to which they're closely related. When this happens, rare diseases can show up. For example, some dogs that were chosen to breed because of their particular looks may also have hip problems. Inbreeding has been quite a problem with dog breeds, especially when people don't check an animal's ancestry carefully.

Figure 4 Labradors are known to have hip problems as the result of many years of inbreeding.

8.6 Check your learning

Remember and understand

1 **Define** the term 'selective breeding'. Give one example in your answer.

2 **Describe** the technology that can be used to assist selective breeding.

3 **Describe** an example of how inbreeding could occur.

4 **Explain** why genetic diversity in a population is important.

Apply and analyse

5 **Explain** why selective breeding is not always a good idea.

6 **Investigate** an example of the difficulties faced by breeding flat-faced pug dogs.

Figure 5 A healthy wheat crop

REVIEW 8

Multiple choice questions

1 Identify what type of reproduction occurs when a bacterial cell divides in two equal parts.
   - **A** cross-pollination
   - **B** parthenogenesis
   - **C** fragmentation
   - **D** binary fission

2 Identify the term used to describe the pollen from one flower being carried to another plant.
   - **A** cross-pollination
   - **B** parthenogenesis
   - **C** fragmentation
   - **D** asexual reproduction

3 Identify the reproductive term used to describe a type of sexual reproduction.
   - **A** cross-pollination
   - **B** parthenogenesis
   - **C** fragmentation
   - **D** binary fission

Short answer questions

Remember and understand

4 **Identify** the scientific term used for ‘making new organisms’.

5 **Define** the term ‘gamete’.

6 **Identify** the common names for the two gametes in animals. **Identify** the common names for the two gametes in plants.

7 **Contrast** a foetus and a baby.

8 **Identify** which produces greater variation: sexual or asexual reproduction.

9 **Describe** the function of a fruit in reproduction.

10 **Describe** why organisms that fertilise internally tend to produce fewer eggs than those that fertilise externally.

11 **Contrast** a spore and a seed.

12 Use your understanding of sexual dimorphism to **describe** three features that differ between a male and a female in humans. **Describe** three features that may differ in birds.

Apply and analyse

13 **Identify** which is better for maintaining biodiversity: self-pollination or cross-pollination. **Justify** your answer (by defining each term, providing an example of the consequences of each process and deciding which will provide the greatest biodiversity).

14 A farmer grows two types of corn on the farm. One type is affected by the frosts in winter but produces really large, juicy corn cobs when it is protected. The other copes in winter without a problem but has only small corn cobs. **Describe** one way the farmer could improve his crops.

15 A 13-year-old girl was keeping a record of her menstrual cycle. She found her cycle lasted approximately 28 days. If her last period started on 1 June, **identify** the following:
   - **a** when she should ovulate
   - **b** when her next period should start.

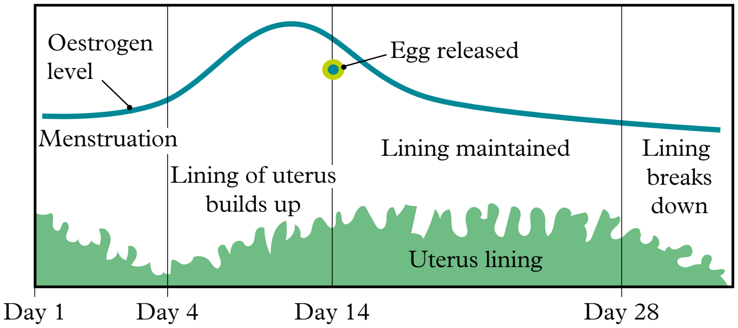


Figure 1 The average 28-day menstrual cycle

16 Examine the images in Figure 2. **Identify** two features that are genetic and two that are environmental.

Figure 2 These dogs are from the same litter.

17 **Explain** why a hermaphrodite reproducing alone would be considered asexual reproduction.

18 Skinks (a type of lizard) drop their tails when threatened, but their tails can grow back. **Explain** why this is this not a type of asexual reproduction.

Evaluate

19 Some reptile eggs are affected by the temperatures they experience while incubating in the nest (see Figure 3). For example, within a single nest, high temperatures will produce female turtles while lower temperatures will produce male turtles. Most nests produce a mixture of

turtle sexes. **Explain** how warmer weather as a result of the enhanced greenhouse effect might impact green sea turtle populations.

Figure 3 Green sea turtle eggs produce female babies when the eggs are warmer and male babies when the eggs are cooler.

20 Use your knowledge of plant reproduction to design a new flower. **Describe** how your flower will reproduce (wind, water, insects or birds). **Create** a picture of your new flower. Label the stamen (with filament and anther), the carpel (with stigma, style and ovary) and the petals of the flower.

Social and ethical thinking

21 When people are deciding if they agree or disagree on a social or ethical issue, they will often base it on their personal experiences. **Explain** what you know about in vitro fertilisation (IVF) techniques. **Identify** where you learnt this information. **Identify** reasons why some people may want to use IVF. **Identify** two reasons why some people may not want to use IVF.

22 Divide into two groups to debate one of the topics below.
  - a Selective breeding is essential to maintain food production for humans.
  - b Reproductive technologies interfere with nature.
  - c Selective breeding is important in preventing extinction.
  - d Genetic diversity can be maintained without technology.

Critical and creative thinking

23 Humans don't reproduce asexually – ever. **Describe** the possible consequences that might occur if a single human was able to reproduce asexually. **Describe** the possible consequences that might occur if many humans were able to reproduce asexually.

24 The life cycles and reproductive strategies of invertebrates are incredibly diverse. Choose an invertebrate to research and present your findings to the class in the form of a poster or webpage. **Investigate** projects that could be shared in a mini-conference format.

Research

25 Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

» Dog breeding in Australia

Some breeds of dogs are vulnerable to genetic problems, such as difficulty breathing or displaced hips, as a result of decades of inbreeding. Research a breed of dog that has such difficulties. Describe the features that these pedigree dogs are judged on in dog shows. Describe the problems that have arisen as a result of the inbreeding. Describe the measures that the RSPCA and the Australian National Kennel Council are taking to ensure these problems do not continue.

» Seed banks

A seed bank stores a large variety of seeds in case a particular species of plant is placed at risk as a result of natural disaster, outbreaks of disease or war. Research a major seed bank near your school. Describe the type of seeds they collect. Identify who collects the seeds for the bank. Describe how the seeds are collected. Describe the conditions that are needed for the seeds to remain viable (alive).

» Chorionic villi sampling (CVS)

Chorionic villi sampling is a procedure that some mothers undergo to test for genetic problems in the foetus. Describe how this procedure is performed. Describe when this test is usually taken. Describe the type of abnormalities that can be detected with this test. Identify an ethical issue that may arise as a result of this test. Describe what genetic counselling is.

» Contraception

Contraception is the term used for the range of methods or devices that are used to prevent pregnancy. Birth control methods have been used for thousands of years. Contrast barrier, surgical and chemical methods of contraception. Research two methods of contraception that can be used by humans. Identify whether males or females use these methods. Describe how effective each of these methods are at preventing pregnancy.

Reflect

The table below outlines a list of things you should be able to do by the end of Chapter 8 ‘Reproducing’. Once you’ve completed the chapter, use the table to reflect on your ability to complete each task.

	I can do this.	I cannot do this yet.
Define asexual reproduction, sexual reproduction, binary fission, parthenogenesis, fragmentation, vegetative reproduction, gamete, offspring and hermaphrodite. Describe asexual and sexual reproduction in terms of genetic similarities between parent and offspring. Describe the influences of nature and nurture on the development of an individual.	☐	☐ Go back to Topic 8.1 ‘There are different ways of reproducing’ Page 154
Describe the female reproductive system including: vagina, uterus, fallopian tubes, ovaries, endometrium and placenta. Explain the main processes involved in the menstrual cycle.	☐	☐ Go back to Topic 8.2 ‘The female reproductive system produces eggs in the ovaries’ Page 156
Define sexually dimorphic, fertilisation, internal fertilisation, external fertilisation, testosterone and oviduct. Describe the main structures and functions of the male reproductive system including: testes, penis, scrotum, epididymis, vas deferens, seminal vesicles and prostate gland. Provide examples of animals that use internal fertilisation and animals that use external fertilisation.	☐	☐ Go back to Topic 8.3 ‘The male reproductive system produces sperm in the testes’ Page 158
Define contraception, inbreeding and desexing. Describe some common problems of the human reproductive systems.	☐	☐ Go back to Topic 8.4 ‘Science as a human endeavour: Things sometimes go wrong in reproduction’ Page 160
Describe the main functions of the reproductive structure of flowers including: anther, stigma, petals, stamen, filament, sepals, ovum, ovary, carpel and style. Explain the process of pollination and fertilisation in plants.	☐	☐ Go back to Topic 8.5 ‘Plant sexual reproduction produces seeds’ Page 162
Describe the purpose of selective breeding. Provide examples of organisms that have been selectively bred and relate selective breeding to a loss of diversity.	☐	☐ Go back to Topic 8.6 ‘Reproduction techniques have an impact on agriculture’ Page 164

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Quizlet Live
Compete in teams to test your knowledge.

Chapter quiz
Test your understanding of this chapter with one of three chapter quizzes.

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Quizlet Live
Launch a quiz for your students on key concepts in this chapter.

CHAPTER 9

EXPERIMENTS

Science lab rules

Being safe in the lab is essential to prevent you and others from getting hurt. Whenever you are in the lab, you must always follow the rules below.

DO:

- wear a lab coat for practical work
- keep your workbooks and paper away from heating equipment, chemicals and flames
- tie long hair back whenever you do an experiment
- wear safety glasses while mixing or heating substances
- tell your teacher immediately if you cut or burn yourself
- tell your teacher immediately if you break any glassware or spill chemicals
- wash your hands after any experiments
- listen to and follow the teacher's instructions
- wear gloves when your teacher instructs you to.

DON'T:

- run in a laboratory
- push others or behave roughly in a laboratory
- eat in a laboratory
- drink from glassware or laboratory taps
- look down into a container or point it at a neighbour when heating or mixing chemicals
- smell gases or mixtures of chemicals directly; instead, waft them near your nose and only when instructed
- mix chemicals at random
- put matches, paper or other substances down the sink
- carry large bottles by the neck
- enter a preparation room without your teacher's permission.

Learning and working in a laboratory

Working in a science laboratory requires you to use a variety of special skills. Many of these you may not use anywhere else. You must know how to identify, prepare and clean up equipment safely to prevent chemicals contaminating future experiments, or harming yourself or someone else.

Wearing lab coats and safety glasses, having hair tied back

Figure 1 Wearing a lab coat and safety glasses is an essential part of completing any experiment.

How to clean equipment

Figure 2 Place warm water in the equipment (e.g. beaker).

Figure 3 Add a small amount of detergent.

Figure 4 Use a brush or cloth to wipe around the equipment.

Figure 5 Clean test tubes using a small bottle brush.

Figure 6 Tip out water and rinse the equipment with fresh water to prevent contamination for the next experiment.

Figure 7 Place the equipment upside down to drain.

What to do with broken glass

Figure 8 Tell your teacher. Place the glass in a special glass bin. Alternatively, wrap the glass in newspaper and dispose of it in the normal rubbish.

⚠ **CAUTION!**
Do not use your hands to pick up the glass.

How to clean up common spills

Figure 9 If it is safe, wipe the spill up with paper towel and dispose of it in the normal rubbish. Can you spot what's wrong with this image? When cleaning up spills, wear gloves to protect your hands!

Figure 10 Let your teacher know straight away if there is a chemical spill. Follow your teacher's directions. Laboratories should have a special spill kit that may be used in these circumstances.

⚠ **CAUTION!**
Tell your teacher first. Wear safety glasses and gloves when cleaning up spills.

Safely smelling chemicals

CAUTION! Check with your teacher if it is safe to smell the chemical, and only proceed if it is.

Figure 11 Hold the chemical slightly away from your face. Use your hand to gently waft a small amount of air above the container towards your face.

How to light a Bunsen burner

CAUTION! Remember to keep your hand below the flame.

Figure 12 Place the Bunsen burner on a heatproof mat.

Figure 13 Connect the rubber hose firmly to the gas tap.

Figure 14 Close the air hole by turning the collar.

Figure 15 Light a match and place it above the barrel, with your hand below the flame.

Figure 16 Open the gas tap fully.

Figure 17 The Bunsen burner will now have a yellow (safety) flame.

1.3B Changing the independent variable

EXPERIMENT

Aim

To determine factors that affect the distance a balloon rocket will travel.

Method

1 Using the balloon rocket you made in Experiment 1.3A in Chapter 1, choose one of the following questions to investigate.
  - What if the balloon was blown up more?
  - What if the string had less friction?
  - What if the string had more friction?
  - What if the straw was shorter?

2 Now, follow these steps.
  - Write a prediction for your enquiry.
  - Identify the *independent* variable that you will change from the first method.
  - Identify the dependent variable that you will measure and observe at the end of the experiment.
  - Identify three variables that you will need to control to ensure a fair test. Describe how you will control them.
  - Write your method as a step-by-step process.
  - Draw a table in which you can record your results.
  - Check your method with your teacher before completing your experiment.
  - Repeat your test at least three times to make sure your results are reliable.

Results

Record your results in the table. Include the units for all measurements.

Discussion

1 Compare (the similarities and differences between) the results of the first method with your method.

2 Use evidence from your results to support or refute (disagree with) your prediction by:
  - describing how you changed the independent variable
  - describing how the results (dependent variable) changed
  - describing how this is similar (supported) or different (refuted) to your prediction.

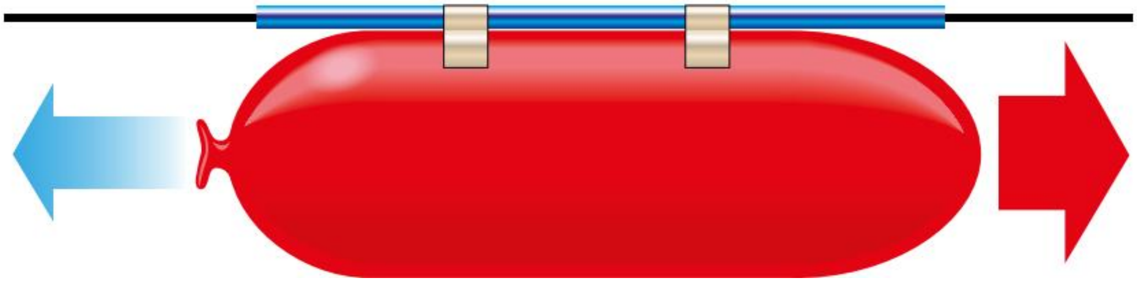


Figure 1 A balloon rocket

1.4 Marshmallow slingshots

EXPERIMENT

CAUTION! Always stand behind the apparatus when firing the marshmallow. Check that no one is in the firing line.

Aim

To determine the relationship between the distance the elastic is pulled back and the distance a marshmallow moves after it is released.

Materials

- Rubber bands
- Plastic ring or pipe cleaners
- Marshmallows
- Chair
- Long tape measure

Method

1. Make a chain of rubber bands by threading the end of one band through and over the end of the second band, then pulling tight.
2. Place a plastic ring in the centre of the rubber band chain.
3. Secure the rubber bands to the legs of an upside-down chair as shown.
4. Insert a marshmallow into the ring.
5. Pull back the marshmallow the measured amount ensuring the elastic is horizontal to the ground.
6. Wait until everyone is out of the flight path, and then release the rubber bands.
7. Measure the distance the marshmallow travelled.

Inquiry: Choose one of the following questions to investigate.

- What if the elastic bands were not horizontal?
- What if the rubber bands were tied tighter?
- What if a smaller marshmallow was used?

Answer the following questions in relation to your inquiry.

- Write a prediction or hypothesis for your inquiry.
- Identify the (independent) variable that you will change from the first method.
- Identify the (dependent) variable that you will measure and/or observe.
- Identify two variables that you will need to control to ensure a fair test. Describe how you will control these variables.
- Write down the method you will use to complete your investigation in your logbook.
- Draw a table to record your results.
- Show your teacher your planning for approval before starting your experiment.

Results

1. Record your results and observations in your table.
2. Use the results you have recorded in your table to draw a graph that shows the distance travelled by the marshmallow at each attempt. Your graph should include:
   - the independent variable labelled on the *x*-axis
   - the dependent variable labelled on the *y*-axis
   - a title for your graph.
3. Describe your results by comparing how you changed the independent variable and how your independent variable changed.

Discussion

1. Identify two variables that were difficult to control. Explain the measures you took to control them.
2. Use evidence from your results to evaluate the accuracy of your hypothesis by describing how the dependent variable changed and comparing it to the prediction you made. If they are similar, then the hypothesis is considered accurate.

Conclusion

Describe the relationship between the distance the elastic is pulled back and the distance a marshmallow moves.

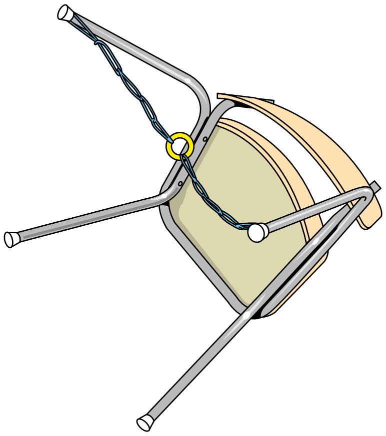


Figure 1 Secure the chain to the legs of a chair.

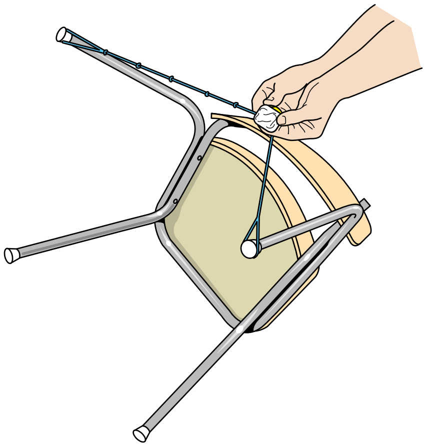


Figure 2 Pull back the marshmallow by the measured amount.

2.1 Identifying rocks

SKILLS LAB

What you need

- Rock samples (unnamed, perhaps labelled A, B, C, D, etc.)
- Hand lens
- Table 1

What to do

1. Examine each rock sample with the hand lens and use the key in Table 1 to identify it. Be aware of the following.
    - Crystals in rocks have straight edges and flat, shiny surfaces.
    - Grains are not shiny, they are jagged or rounded and more like grains of sand.
    - Coarse grains are about the size of a grain of rice. Medium grains are smaller but still visible to the naked eye and small grains are only visible with a hand lens or magnifier.
2. Display your results in a table that identifies the rock sample (e.g. sample A), lists its main properties and gives its name.

Questions

1. Describe any difficulties you had when identifying your rock samples.
2. Make a note of any samples that you could not identify.
3. Compare your results with those of another group. Identify any differences between your results and the other groups'.
4. Ask your teacher for the names of your rock samples and highlight the rocks that you correctly identified (hopefully all of them).

Table 1 Key for common types of rocks

1	Does the rock have layers? (Use a magnifying glass to check.)	Yes – Go to 3; No – Go to 2
2	Can you see cracks in the rock?	Yes – Go to 4; No – Go to 5
3	Can sand be rubbed off the rock?	Yes – Sandstone; No – Go to 8
4	Is the rock a light colour (i.e. mostly white)?	Yes – Marble; No – Go to 10
5	Does the rock look like glass?	Yes – Obsidian; No – Go to 6
6	Does the rock have a lot of holes that make it light to hold?	Yes – Pumice; No – Go to 7
7	Is the rock grey to black?	Yes – Basalt; No – Limestone
8	Can you see crystals in the rock?	Yes – Gneiss; No – Go to 9
9	Can you see layers of thin, flat pieces of rock? Could the rock be split easily?	Yes – Slate; No – Shale
10	Does the rock have a lot of holes that make it light to hold?	Yes – Pumice; No – Granite

2.2 Testing the hardness of common substances

SKILLS LAB

What you need

- 5 cm long iron nail for scratching tool
- Samples of:
    - glass microscope slide
    - disposable plastic Petri dish
    - 2 cm × 5 cm piece of copper sheet
    - half a stick of chalk

What to do

1. Using the nail, scratch the objects and rank them from softest to hardest. When testing the hardness, scratch only a small part of the mineral or object. A 5-cm-long scratch is all that is needed.
2. Identify the sample that did not become scratched (the hardest).
3. Identify the sample that did become scratched (the softest).
4. Collect some mineral samples. Arrange them in order of hardness. Minerals such as feldspar, quartz and calcite are listed in Table 1 on page 21.

Questions

1. Write the order of hardness in your logbook, from softest to hardest.
2. Compare (the similarities and differences between) your results with those of other groups. Use examples as evidence to support your answer.
3. Explain the phrase 'Hardness of a rock is a relative measurement'.

2.3 Testing the minerals in toothpaste

EXPERIMENT

Aim

To determine which brands of toothpaste, and which minerals, are most effective in removing a stain from porcelain tiles.

Materials

- 3 porcelain tiles
- Toothbrush
- Water
- Permanent marker
- Toothpaste (at least three brands)

Method

1 Record the list of ingredients in the toothpaste.
2 Use the permanent marker to make a cross in the centre of each porcelain tile.
3 Put a pea-sized amount of toothpaste on the toothbrush. Brush one of the marked tiles 50 times in one direction. Try to use the same force with each stroke.
4 Record how many strokes it took to remove the mark from the tile.
5 Use the water to rinse off the toothbrush thoroughly.
6 Repeat this measurement three times for this toothpaste.

Inquiry: What if another toothpaste, with different minerals, was used to remove a stain?

- Write a prediction or hypothesis for your inquiry.
- Identify the (independent) variable that you will change from the first method.
- Identify the (dependent) variable that you will measure and/or observe.
- Identify two variables that you will need to control to ensure a fair test. Describe how you will control these variables.
- Write down the method you will use to complete your investigation.
- Show your teacher your planning for approval before starting your experiment.

Results

Copy and complete Table 1 to show the number of strokes required to clean the tile.

Discussion

1 Explain why you repeated each measurement three times.
2 Identify the brand of toothpaste that was most effective in cleaning the mark off the tiles.
3 Many false teeth are made of porcelain. Describe the recommendations that you would make to a person with porcelain teeth.
4 Describe the function of fluoride in toothpaste.
5 Excess fluoride ingestion (swallowed) causes fluorosis – a condition in which developing teeth become discoloured. Describe why young children may be vulnerable to this condition.

Conclusion

Describe the role of each of the following minerals in toothpaste.

- fluorite
- mica
- sand/silica
- sodium carbonate

Figure 1 What minerals are found in different brands of toothpaste?

Table 1 Toothpaste and mineral experiment

Toothpaste brand	Minerals present	Number of strokes required				Observations
		Attempt 1	Attempt 2	Attempt 3	Average	

2.4 What affects crystal size?

EXPERIMENT

Aim

To grow crystals and determine what affects their size.

Materials

- Alum solution
- Bunsen burner
- Heatproof mat
- Matches
- Tripod
- Gauze mat
- 2 Petri dishes
- Evaporating dish
- Safety glasses
- 250 mL beaker
- Tablespoon

Method

1. Prepare a solution of alum by mixing 2½ tablespoons of alum with ½ cup of hot water. Stir until the alum is dissolved.
2. Pour roughly equal amounts of alum solution into the evaporating dish and the two Petri dishes.
3. Put one of the Petri dishes in the refrigerator.
4. Put the other Petri dish on a window sill.
5. Place the heatproof mat under the Bunsen burner and place the evaporating dish on the gauze mat.
6. While wearing safety glasses, gently heat the evaporating dish containing the alum solution over a yellow (safety) flame. The yellow flame is cooler and will allow for gentle boiling.
7. Continue heating the solution until nearly all the water has evaporated. Stand back from the evaporating dish and the solution while heating as the solution may spit and splatter.
8. Observe the size of the crystals formed in the evaporating dish. Turn off the gas when the water is almost gone and allow to cool. Store the crystals in a cool dry place.
9. After 2 days, compare the size of the crystals formed by heating quickly to the crystals formed slowly on the window sill.
10. Observe the crystals formed in the refrigerator again after 4 or 5 days.

Results

Draw a labelled diagram of the crystals formed in the evaporating dish and in the two Petri dishes. Your diagram needs to show the different sizes of the crystals in the different dishes.

Discussion

1. Identify the independent variable for this experiment.
2. Identify the dependent variable.
3. Name three variables you needed to control. How were these controlled?
4. Each of these crystals grew over a different time span. Describe how allowing the crystals to form slowly affected the size of the crystal.

Conclusion

Describe what you learnt about the factors affecting crystal size.

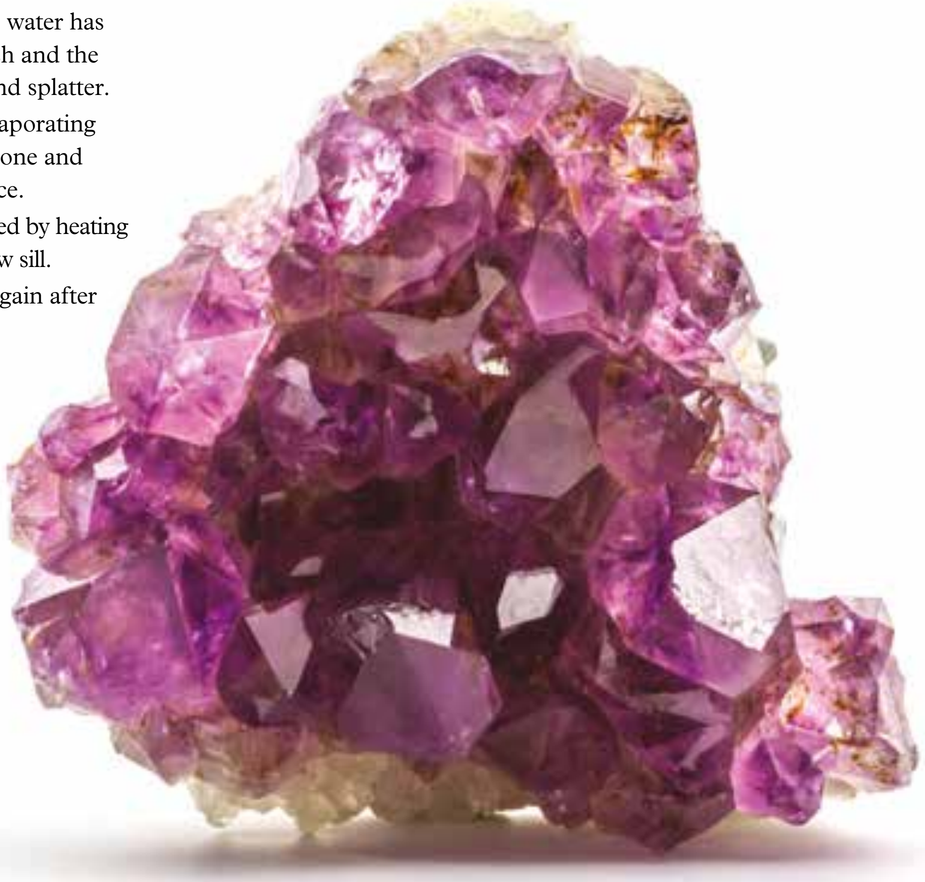


Figure 1 Different factors can affect the size of a crystal.

2.5 Making sedimentary rocks

EXPERIMENT

Aim

To make small samples of sedimentary rocks and compare them against real samples.

Materials

- Dry clay
- Dry sand
- Plaster of Paris
- Small, smooth pebbles
- Samples of sedimentary rocks
- Water
- Mortar and pestle
- Teaspoon
- 4 empty matchboxes
- White tile

Method

1. Grind a lump of dry clay with a mortar and pestle until it is fine and powdery.
2. Using the teaspoon, mix the dry ingredients for each rock sample on the white tile according to the recipes in Table 1, but don't add the water just yet. You will need to prepare two shale samples to use in Experiment 2.6.
3. Pile up your ingredients into a little hill and make a small dip in the centre for the water.
4. Slowly add the water and stir until the ingredients are uniformly mixed. Be careful not to make the mixture too wet.
5. Press your mixture into an empty matchbox, label it with the rock type and your name and leave it to dry for 2 days.
6. When your 'rock' is dry, peel off the matchbox and examine your sample. Take digital photos of your samples and photos of the 'real' rocks for comparison. Keep your two shale samples for Experiment 2.6.

Results

Include images of your rocks. Describe what your rocks look like using the terms in Topic 2.1 (page 18).

Discussion

1. Describe how sedimentary rocks are formed.
2. Explain how fossils are formed in sedimentary rocks.
3. Compare the similarities and differences between your rocks and other sedimentary rocks that you have seen.

Conclusion

Describe the characteristics that are unique to sedimentary rocks.

Table 1 Sedimentary rock experiment

Rock	Number of teaspoons				
	dry clay	sand	plaster of Paris	pebbles	water
Sandstone	½	4	½	0	2
Shale	5	½	0	0	2
Conglomerate	½	1	½	4	2

Figure 1 Sedimentary rock cliffs

2.6 Making a metamorphic rock

EXPERIMENT

Aim

To make a sample of a metamorphic rock.

Materials

- 2 shale rock samples from Experiment 2.5
- Bunsen burner
- Matches
- Heatproof gloves
- Tripod
- Pipe clay triangle
- Gauze mat
- Evaporating dish
- Tongs
- 2 × 250 mL beakers

Method

1. Allow your shale samples from Experiment 2.5 to dry for approximately 1 week.
2. Place one of the shale samples on a pipe clay triangle on top of a gauze mat and heat strongly over a blue Bunsen burner flame for about half an hour. You could place an evaporating dish upside down over the shale to retain more heat.
3. After about 30 minutes of heating, allow the sample to cool for 10 minutes. Then, use the tongs to carefully pick up the shale sample and drop it into a beaker of water.
4. Drop the second, unheated shale sample into another beaker of water and observe what happens to the two rock samples.

Results

Record your observations in a table.

Discussion

1. Contrast (the differences between) the two rock samples when they are dropped into the water.
2. Explain how strong heat can change the properties of rocks over time.
3. Compare (the similarities and differences between) your new metamorphic rock sample with the original shale sample.

Conclusion

Describe what you know about the formation of metamorphic rocks.

Figure 1 Metamorphic rock

2.7 Modelling the rock cycle

SKILLS LAB

What you need

- Crayons (3 different colours)
- Sharpener
- 2 sheets of aluminium foil
- 2 wooden blocks
- Beaker
- Bunsen burner
- Heatproof mat
- Large clamp
- Tripod
- Gauze mat
- Stirring rod
- Matches

What to do

1 Remove the paper from the crayons.
2 Shave the crayons into small piles. Keep each colour in a separate pile.
3 Cover one wooden block with aluminium foil.
4 Sprinkle a layer of crayon shavings over the aluminium foil to form the first layer.
5 Repeat step 4 for the remaining colours of crayons.
6 Cover the layers of crayons with another sheet of aluminium foil.
7 Place the second wooden block on top of the foil and press down with as much pressure as possible.
8 Remove the top block and aluminium foil and examine the compacted shavings.
9 Place the shavings between the aluminium foil and wooden blocks again.
10 Apply the large clamp around the wooden blocks and shavings. Tighten the clamp as much as possible.
11 Remove the clamp and examine the compacted crayon shavings.
12 Place the compacted crayon shavings into the beaker and place the heatproof mat under the Bunsen burner.
13 Heat the compacted crayon shavings over the Bunsen burner, stirring occasionally until all lumps are removed.
14 Allow the crayon mixture to cool in the beaker.
15 Examine the resulting crayon sample.

Questions

1 Describe the type of weathering (mechanical or chemical) that took place at step 2.
2 Identify the term used to describe the movement of the sediment pile of crayon shavings onto the aluminium foil at step 4.
3 Identify the type of rock formed in step 8.
4 Identify the type of rock formed in step 11.
5 Identify the type of rock formed in step 15.
6 Compare (the similarities and differences between) the three forms of rock you created.

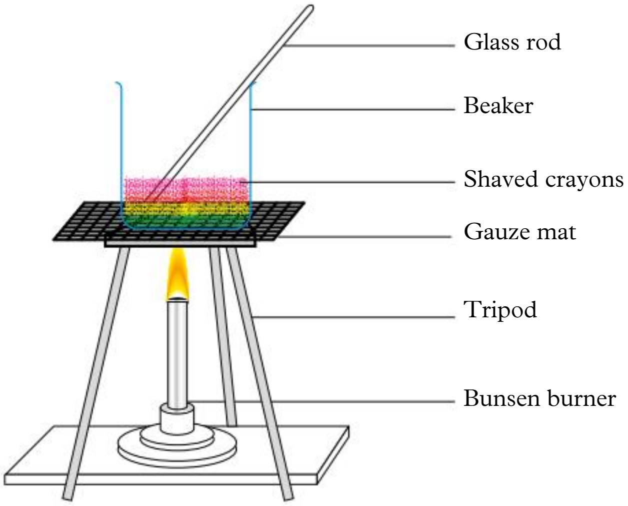


Figure 1 Experimental set-up

Figure 2 Colourful crayons

2.8 Preventing soil erosion

CHALLENGE

Design brief

Design a way to prevent a 5 cm layer of soil in a large foil lasagne dish from being eroded when water is poured from a watering can. The lasagne dish should be set at an angle to the bench.

Criteria restrictions

- Pebbles can be no larger than 1.5 cm in diameter.
- Sticks must be less than 5 cm long.
- Artificial materials must not be toxic to the environment.
- No more than 1 cup of material may be added.
- A maximum amount of soil must still be available for cultivation.

Questioning and predicting

- Describe how you will prevent the soil from being washed away.

Planning and conducting

- Identify the materials that you will use.
- Draw a diagram that shows where you will position the materials on the lasagne tray.
- Place the 5 cm of soil in the base of the lasagne dish.
- Arrange the remaining materials on the top of the soil to match your diagram.
- Raise one end of the lasagne dish up so that the dish is on an angle.
- Fill a watering can with water and pour the water on the upper end of the dish.
- Observe how the soil moves with the water.
- Figure 2 shows the general set-up of the experiment.

Processing, analysing and evaluating

1. Describe how the soil moved with the moving water.
2. Identify the most successful feature of your design.
3. Describe the limitations (what did not work) of your design.
4. Evaluate whether it would be possible to create a large-scale version of your design (by calculating the amount of material that would be needed to prevent a small hill from being eroded, and deciding if it would be possible to complete).
5. If you were doing this experiment again, explain how you would modify your design.

Communicating

Present the various stages of your investigation in a formal experimental report.

Figure 1 Soil erosion

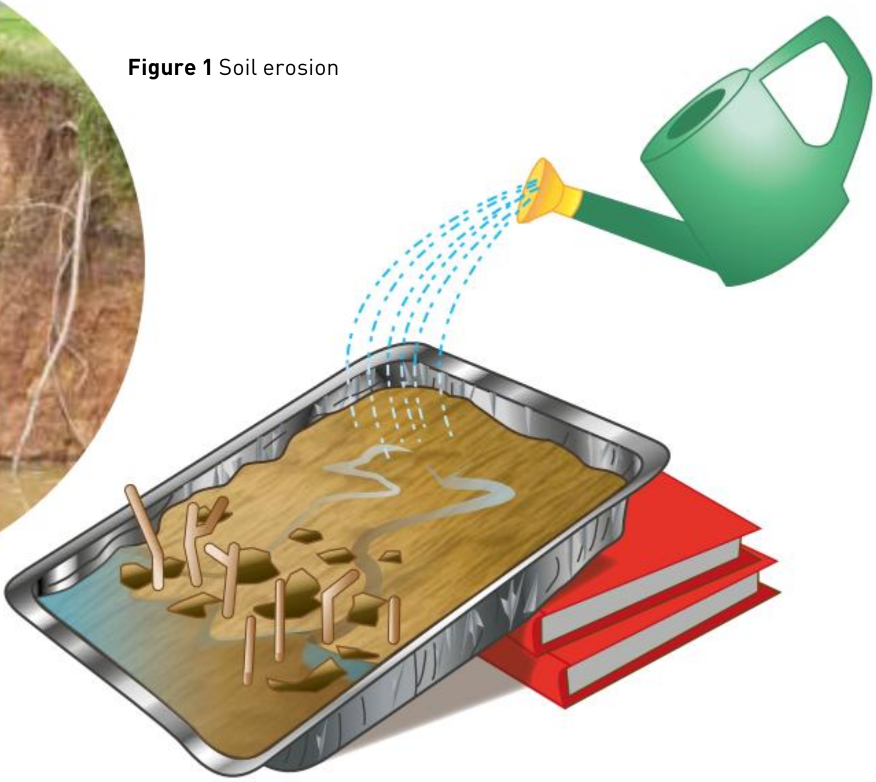


Figure 2 Experimental set-up

2.9 Copper treasure hunt

EXPERIMENT

You are a geologist employed to identify the location of new copper sources. You have used geophysical testing to determine a region around Mount Isa that has an intense electrical chargeability. You decide to complete a series of geochemical tests on the river silt to identify a possible source of the metal.

Aim

To determine the location of a source of copper mineral from samples collected along a river.

Materials

- Wire loops
- 0.1 M hydrochloric acid
- Bunsen burner
- Heatproof mat
- Matches
- Soil samples 1–6

NOTE: Samples with lower numbers contain 1 teaspoon of copper sulphate dissolved in 5 teaspoons of water. This will be mixed into a thick slurry with 13 teaspoons of sand. Samples with higher numbers have no added copper sulphate.

Method

1. Set up your Bunsen burner on the heatproof mat, observing safety instructions, and light your Bunsen burner on the safety flame.
2. Adjust your Bunsen burner to the blue flame. Take a wire loop and dip it in a small beaker of 0.1 M hydrochloric acid. Flame the loop. This will clean the loop, ready for your soil sample. Avoid getting too close to the flame. Stand back a little.
3. Take a loop of the soil sample and place it in the flame. Observe the colour of the flame. A green flame suggests copper is in the soil sample. No green colour suggests the copper is further downstream.
4. Once you have finished your observation, dip the loop in the 0.1 M hydrochloric acid again and re-flame it. This will clean your loop for the next sample.

Results

Include your results in a table.

Discussion

1. Describe the possible location of the source of copper. Describe the evidence that supports your claim.
2. Explain why you cleaned the loop between each test.
3. Evaluate whether this geochemical method could be used if the copper ore was located deep under the ground (by describing how buried copper ore is different to surface ore and deciding if this would affect the results of the experiment).
4. Describe how you would test for copper ore that was located well below the Earth's surface.

Conclusion

Describe what geochemical testing is and how it is used to test for minerals.

Figure 1 Copper

3.1 Draw flow diagrams of energy transfer

SKILLS LAB

What you need

- Station 1: A variety of wind-up toys
- Station 2: Battery, wires, small buzzer
- Station 3: Tuning fork
- Station 4: Plastic cup, water, salt, aluminium strip, copper strip, 2 wires, multimeter
- Station 5: Plastic windmill, kettle
- Station 6: Toy car, ramp, measuring tape

What to do

Spread around the room are stations with different types of energy. Copy Table 1 from the next page into your lab book. Follow the steps below for each station and identify the object where you first see evidence of the energy (source), and the object where you last see the energy (output).

Station 1

1 Wind up the toys and watch them move. Identify the source and output energy.

Figure 1 Station 1 What path does the energy take as it is transferred through the wind-up toys?

Station 2

1 Connect the battery to a buzzer. Identify the source and output energy.

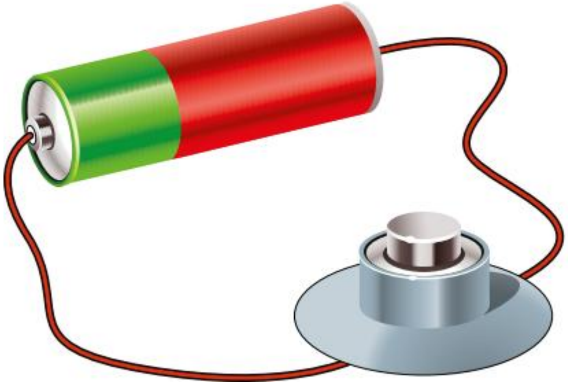


Figure 2 Station 2 Use wires to connect the buzzer to the battery.

Station 3

1 Gently tap the forked end of the tuning fork on the table.

2 All sound is generated by vibrations. Identify the source and output energy.

Figure 3 Station 3 Where does the sound energy come from or transfer from?

Station 4

1 Fill most of the cup with water.

2 Add 1 tablespoon of salt to the water.

3 Fold a strip of aluminium and a strip of copper over opposite sides of the cup so that one end is in the saltwater and the other end is on the outside of the cup.

4 Attach wires to the outside edges of the metal strips.

5 Connect the multimeter to the wires and adjust the multimeter so the voltage is measured.

6 Record the voltage generated by your chemical battery. Identify the source and output energy.

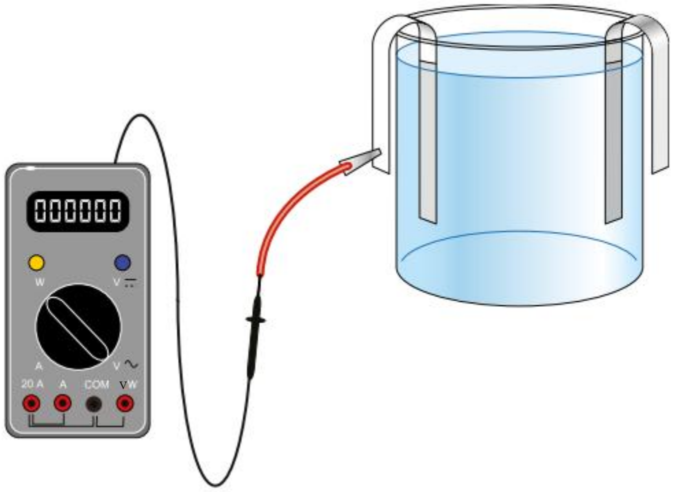


Figure 4 Station 4 Connect the saltwater battery to a multimeter.

Station 5

1 Blow on the plastic windmill. Identify the source and output energy.
2 Hold the plastic windmill over a boiling kettle while being careful not to burn yourself with the steam. Hold your hand as far away as possible from the steam. Ensure there is plenty of water in the kettle so it doesn't boil dry. Identify the source and output energy.

Figure 5 Station 5 A toy windmill acts like an electricity-generating turbine.

Station 6

1 Set up the ramp so that the top end is 10 cm above the ground.
2 Place the car at the top of the ramp.
3 Allow the car to roll down the ramp and along the floor.
4 Measure how far the car rolled. Identify the source and output energy.
5 Describe how could you increase this energy.

Figure 6 Tape measure

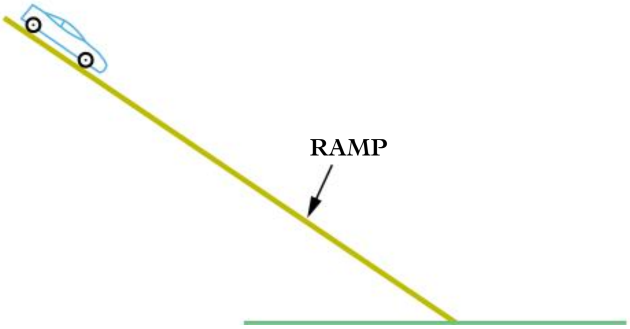


Figure 7 Station 6 What path does the energy take as the car moves down the ramp?

Results

Table 1 Energy transfer

Station	Where does the energy come from?	Which object or part of the object has the energy last?
1		
2		
3		
4		
5		
6		

Questions

1 Describe what is meant by 'energy transfer'.
2 Identify which stations had energy transfer from one object to another.
3 Draw an energy flow diagram for each station.
4 Describe the original energy source for all of the stations and all objects on Earth.

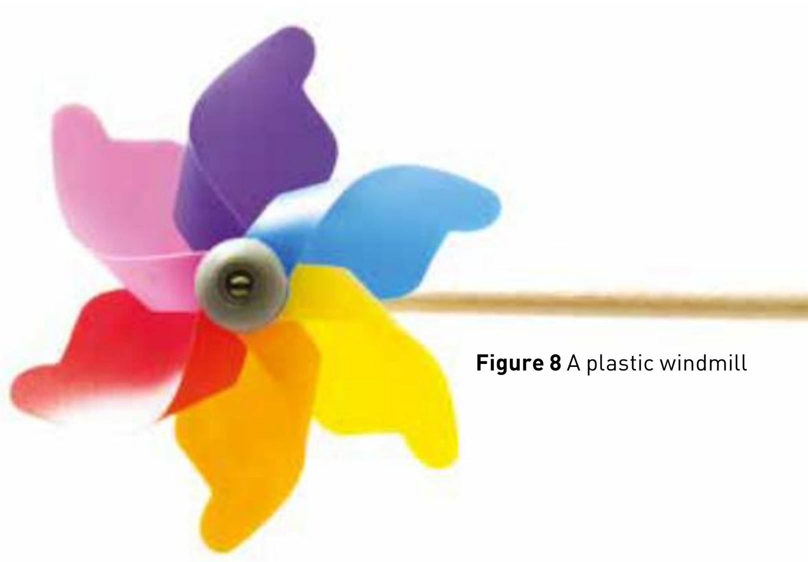


Figure 8 A plastic windmill

Figure 9 At a standstill

3.2 What if the amount of elastic potential energy was increased?

EXPERIMENT

Aim

To investigate how elastic potential energy can be used to power a boat.

Materials

- Waxed cardboard (fruit boxes work well)
- Scissors
- Rubber band
- Butterfly pins
- Water bath or swimming pool

Method

1. Cut out the waxed cardboard to match the diagram in Figure 1.
2. Put the rubber band around the propeller and attach it to the boat using butterfly pins.
3. Wind the propeller anticlockwise (when viewed from the right side of the boat), place the boat in the water and release it.
4. Measure how far the boat travels.

Inquiry: What if more elastic potential energy was stored in the rubber band propeller?

- Write a prediction or hypothesis for your inquiry.
- Identify the (independent) variable that you will change from the first method.
- Identify the (dependent) variable that you will measure and/or observe.
- Identify two variables that you will need to control to ensure a fair test. Describe how you will control these variables.
- Write down the method you will use to complete your investigation in your logbook.
- Draw a table to record your results.
- Show your teacher your planning for approval before starting your experiment.

Results

Complete Table 1.

Draw a line graph showing the effect of increasing the elastic potential energy of the propeller on the distance the boat travelled.

Discussion

1. Identify the type of data as either qualitative or quantitative. Justify your answer (by defining each term and comparing it to your data).
2. Explain why you made three attempts at each propeller rotation to determine the average distance travelled.
3. Identify the type of energy that the elastic potential energy was transformed into.
4. Your hands provided the energy to wind the propeller. Describe where this energy came from.

Conclusion

Describe the relationship between the potential energy given to the propeller and the distance the boat moved.

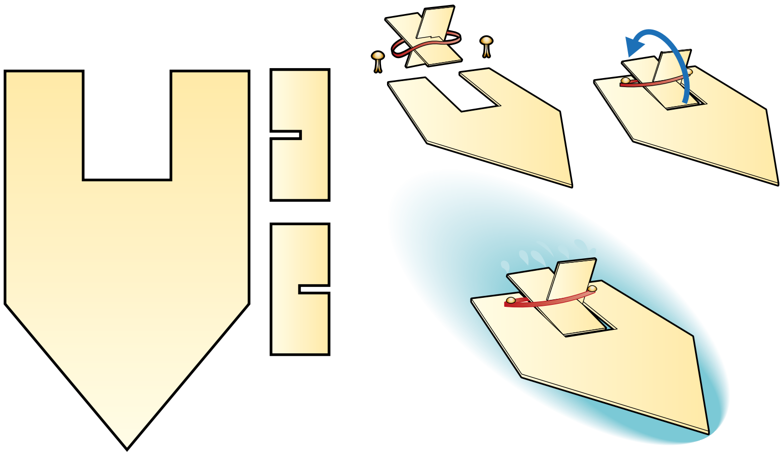


Figure 1 The parts and method of assembly for a rubber band boat

Table 1 Potential energy experiment

Number of rotations of the propeller	Distance the boat travelled Attempt 1	Distance the boat travelled Attempt 2	Distance the boat travelled Attempt 3	Average distance the boat travelled
1				
2				
3				
4				
5				

3.3 Exploring sound energy

CHALLENGE

What you need

- Tuning fork
- Wooden table, wooden box or resonance box
- Electric guitar
- Acoustic guitar

What to do

1 Hit a tuning fork on the sole of your shoe and then listen to the sound it makes.

2 Repeat the process but this time hit the tuning fork on the sole of your shoe and then hold or stand it upright on a wooden table, wooden box or resonance box. Describe the difference the table, wooden box or resonance box made to the loudness of the sound.

3 Repeat the process again but this time place your finger against the table or box. Explain why the table or box was vibrating.

4 If possible, compare the sound of an unplugged electric guitar to that of an acoustic guitar. Describe which is louder. Explain why this guitar is louder.

5 Now place your hand on the body of the acoustic guitar as it is played. Identify the vibrations. Identify whether there are any vibrations on the electric guitar. Use this information to explain why the acoustic guitar may be louder.

Questions

1 Explain how you could change the way you play a recorder so that it gives out more sound energy.

2 Explain how a pianist manages to play some notes softly and others very loudly.

3 When you want to yell or speak louder, explain how you make the sound coming from your mouth louder.

4 Explain how drummers make their drums sound louder.

Figure 1 How does a guitar create sound energy?

3.4 Energy converters

CHALLENGE

What you need

Table 1 Common devices that convert energy

Device	Energy input	Energy output
Drum		Sound
Hydroelectricity	Gravitational	
	Electrical	Sound
Light bulb		Light
Battery	Chemical	
Car engine		Kinetic
	Elastic	Kinetic
Gas heater		Heat
	Nuclear	Light
Solar panel	Solar energy	
Phone charger		Electrical

What to do

1 Work in groups to fill in the gaps in Table 1.

2 Discuss any patterns you see in the table. For example, are there any energy types that are more commonly 'inputs' rather than 'outputs'?

3 Extend the list with five more devices your group comes up with.

Questions

1 Draw a flow diagram that shows the direction of energy flow in a drum.

2 Define the term 'potential energy'.

3 Identify a device that transforms potential energy into kinetic energy.

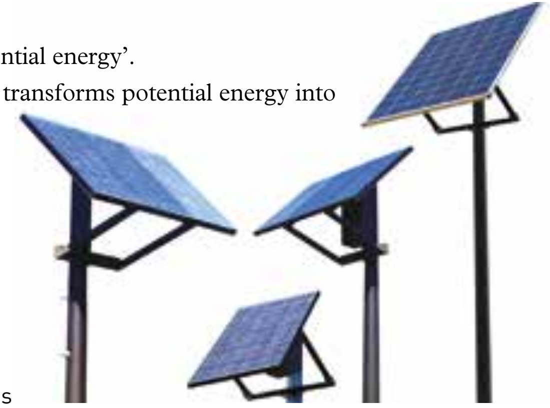


Figure 1 Solar panels

3.5 What if you bounced a ball?

EXPERIMENT

Aim

To investigate the energy efficiency of a bouncing ball.

Materials

- Tennis ball
- Metre ruler
- A selection of other types of balls
- Blu-Tack or masking tape

Method

1 Hold the tennis ball 1 m above the ground next to the vertical ruler.

2 Drop the ball (do not throw it) on a hard surface.

3 Use the metre ruler to measure how high the ball bounces back. Be careful to avoid parallax error by ensuring your eye is level with the ball.

4 Determine the percentage energy efficiency by using the formula below:

$$\text{Percentage efficiency} = \frac{\text{height of bounce}}{\text{starting height}} \times \frac{100}{1}$$

Inquiry: Choose one of the following questions to investigate.

- What if another ball was bounced on the same surface? (Does it have the same efficiency?)
- What if the same ball was bounced on another surface? (Does it have the same efficiency?)

Answer the following questions in relation to your inquiry.

- Write a prediction or hypothesis for your inquiry.
- Identify the (independent) variable that you will change from the first method.
- Identify the (dependent) variable that you will measure and/or observe.
- Identify two variables that you will need to control to ensure a fair test. Describe how you will control these variables.
- Write down the method you will use to complete your investigation in your logbook.
- Draw a table to record your results.
- Show your teacher your planning for approval before starting your experiment.

Results

1 Complete Table 1.

2 Draw a column graph showing how the energy efficiency of the balls changed with your independent variable.

Discussion

1 Describe the results of your experiment by describing how you changed the independent variable and how this affected the dependent variable.

2 Compare (the similarities and differences between) the results of your experiment to your hypothesis.

3 Identify the type of energy the ball had:
  - before it was dropped
  - just before it hit the ground
  - as it touched the ground.

4 Identify the waste energy.

5 Draw a flow diagram of the energy transformation.

6 Draw a flow diagram of the energy transfer.

Conclusion

Describe how the independent variable affected the dependent variable.

Table 1 Bouncing ball experiment

Independent variable (surface/ball)	Height of bounce			Average height of bounce	Efficiency (%)
	Attempt 1	Attempt 2	Attempt 3		

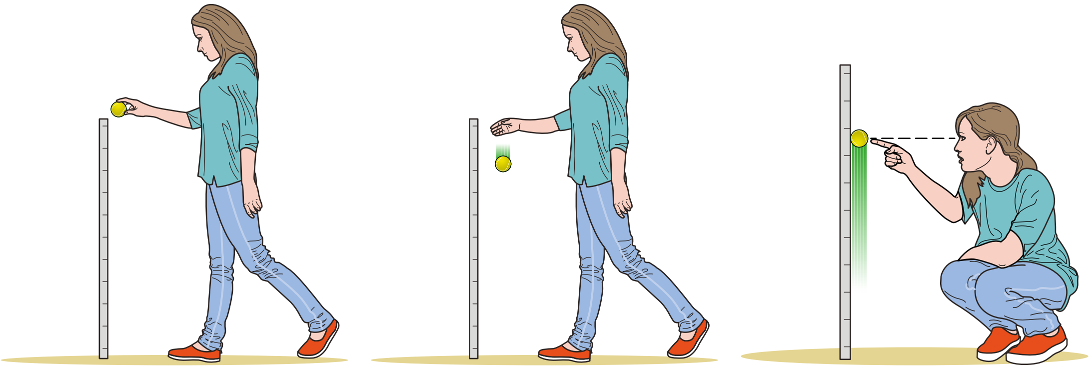


Figure 1 Experimental set-up

3.6 Design an energy-efficient house

CHALLENGE

Design brief

Design and build two identical houses out of cardboard or wood. Add a feature to one of the houses that will make it more efficient in staying cool. Test your design feature by exposing both houses to an energy source (a strong light) and determine the rate of temperature increase for each house. You should consider any safety issues and discuss these with your teacher prior to testing.

Criteria restrictions

- Only one feature may be added to the second house.
- The feature must represent a design feature that is currently available to home owners.
- The feature must be proportionate in size to the house.

Questioning and predicting

- Identify the feature you will add.
- Identify the materials you will use.
- Use your knowledge of heat energy to explain why your added feature will keep the house cool.

Planning and conducting

- Explain how you will measure the temperature of the two houses.
- Describe how long you will expose the houses to the energy source.

Processing, analysing and evaluating

1. Describe the rate of temperature increase in both houses.
2. Describe how efficient your feature was at preventing the transfer of thermal energy.
3. Describe the limitations of your design (when it will not prevent thermal transfer).
4. Describe how you could create a large-scale version of your design for a real house.
5. Describe how you would modify your design if you were doing this experiment again.

Communicating

Present the various stages of your investigation in a formal experimental report.

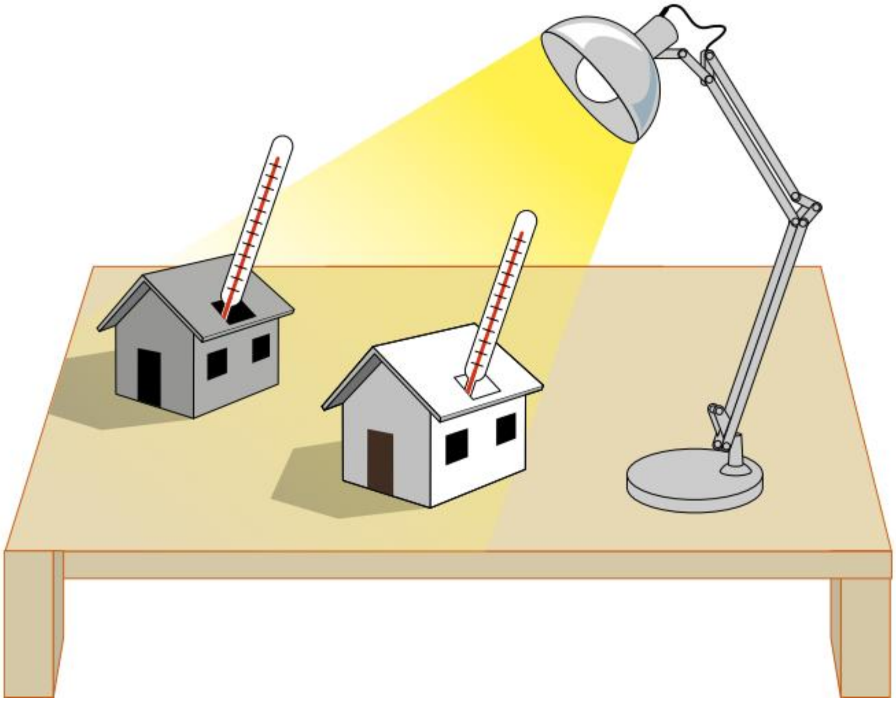


Figure 1 General set-up of experiment

3.7A Leakywater Council swimming pool and waterslide

CHALLENGE

Design brief

The Leakywater Council invites suitably qualified and experienced students to construct a prototype waterslide to supplement the Leakywater Olympic Swimming Pool. The waterslide must engage children of all ages in safe play. All people who use the waterslide should have enough gravitational potential energy to transform into effective kinetic energy (and speed) at the base of the slide.

Criteria restrictions

The prototype (scale model) should comprise all parts of a successful waterslide that engages children of all ages in safe play. Your prototype tower must be built from the list of materials in Table 1 on the next page. You must supply your own materials.

Questioning and predicting

- Describe the features that a waterslide should have.
- Describe the restrictions that the council would put on the design of a waterslide. (Remember that as a body loses height it loses gravitational potential energy and gains kinetic energy (i.e. it speeds up). You don't want people travelling too fast on the slide.)
- Identify the width of your support tower that will be needed to support the slide.
- Identify the height of your model tower.

Planning and conducting

- Draw a labelled diagram of your waterslide.
- Find examples of waterslides that show the types of design you could use for your support structure.
- Describe how the example waterslides support the height and weight of the slides.
- Describe how the example waterslides provide access to the top of the slide.
- Keep safety in mind. You don't want someone falling out of the slide.
- Describe how the structure is going to be held together.
- Identify the parts of the design that may be difficult to build.
- Identify possible parts of your model that may be weak before you begin building. Describe how these areas can be strengthened.
- Identify the materials that you will use to build your prototype. All materials have a cost. Consider the materials listed in Table 1 (and any others you can think of) and choose those that you would use for each component of your waterslide prototype.

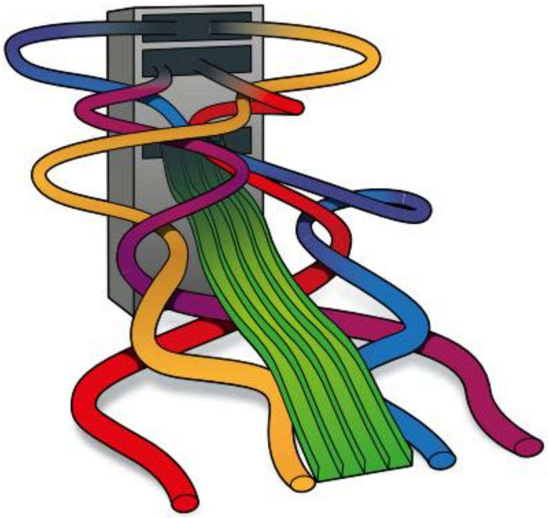


Figure 1 Waterslides convert gravitational potential energy to kinetic energy.

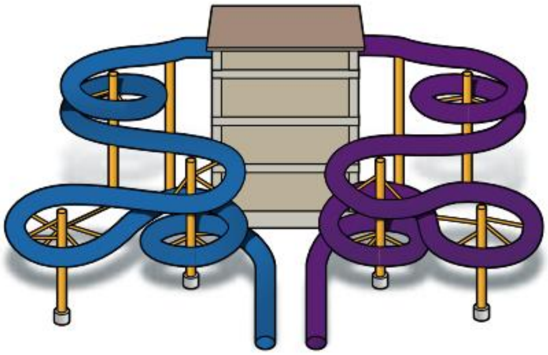


Figure 2 Long waterslides have more friction than short waterslides.

Table 1 Materials and their approximate costs

Material	Approximate cost	Material	Approximate cost
Garden hose	$5 per metre	Pipe cleaners	$2 for 20
Toilet rolls	$0.75 each	Paper clips	$3 for 30
Icy pole sticks	$5 for 20	Cardboard box	$2 each
Toothpicks	$3 for 50	Lunch box	$6 each
Sticky tape	$2.50 per roll	PVC tube	$8 each
Blu-Tack	$1 per strip	Plasticine	$4 for 250 g
Wooden rulers	$2 each	Newspaper	$2 each
Plastic rulers	$3 each	Chopsticks	$1 each
Bubble wrap	$1 per metre	Forks	$1.50 each
Wooden rods	$1 each	Plastic wrap	$4 per roll
Ice-cream containers	$4 per container	Plastic bag	$0.10 each

Processing, analysing and evaluating

1. Identify the weight your tower supports. Describe how it can be made stronger.
2. Identify any other materials that could be used to improve the performance of the tower.
3. Calculate the cost of the prototype. Compare this cost to the cost of the full-size water slide.

Communicating

Present the various stages of your investigation in a formal experimental report.

Figure 3 You may need to test a variety of materials to determine their suitability for your waterslide.

Figure 4 The amount of kinetic energy a person has at the bottom of a waterslide often indicates the success of the design.

3.7B Investigating structures and materials using icy pole sticks

EXPERIMENT

CAUTION! It may be worth performing this investigation outside or where the water will do the least amount of damage.

Aim

To investigate the difference in structural capacity (how much weight it can hold) of the icy pole beam based on the way it is arranged.

Materials

- Icy pole sticks (at least six per group)
- 2 small blocks of timber with a 1.5 mm slot cut across them to hold the 'beam'
- A bucket with a handle
- A second bucket full of water
- 100 mL measuring cylinder or jug
- Blu-Tack

This experiment uses icy pole stick beams to investigate elements of structure such as the beams in buildings and bridges.

Method

1 Place an icy pole stick across the slots on the two blocks of timber to act as a 'beam' on its side.

2 Hang the empty bucket from the centre of the 'beam'. The bucket needs to be suspended no more than 10–15 cm above the ground.

3 Add water to the bucket, 100 mL at a time. Record how much water is needed to make the 'beam' break.

4 Draw a picture of the break in the icy pole stick.

5 Repeat this procedure twice more to determine an average breaking weight for the 'beam'.

6 Describe the way the icy pole stick broke.

Inquiry: What if the 'beam' is placed flat?

- Write a prediction or hypothesis for your inquiry.
- Identify the (independent) variable that you will change from the first method.
- Identify the (dependent) variable that you will measure and/or observe.
- Identify two variables that you will need to control to ensure a fair test. Describe how you will control these variables.
- Write down the method you will use to complete your investigation in your logbook.
- Draw a table to record your results.
- Show your teacher your planning for approval before starting your experiment.

Results

Draw a table to show your results.

Discussion

1 The 'beams' were both the same size. Compare the two ways the 'beams' were tested.

2 Compare the amount of weight that was held by each 'beam' arrangement.

3 Evaluate the orientation that would be more suitable for construction. Use the answers to the previous questions to justify your answer.

Conclusion

Describe how the structural capacity of the beam is affected by its orientation.

Figure 1 Icy pole sticks

3.8 The Sun's energy

CHALLENGE

What you need

- Solar cell
- Motor with propeller
- Wires
- Sunshine
- Timer

What to do

1 Connect the solar panel to the motor using the wires.
2 Record the weather conditions.
3 Expose the solar panel to sunshine. Count how many times the propeller rotates in 1 minute.
4 Repeat this test at different times of the day, or on different days.
5 Record your data in Table 1.

Questions

1 Identify the time of day that the Sun produces the most light energy.
2 Explain why you should take many readings over several days.
3 Explain why you needed to record the weather conditions.
4 Draw a flow diagram that shows the energy transformations for your challenge.

Figure 1 The Sun is a big source of energy.

Table 1 Record of propeller rotations

Date	Time	Revolutions of propeller/minute	Weather conditions

4.1 Modelling sound waves

CHALLENGE

What you need

- Slinky spring
- Pipe cleaner

What to do

1 Twist a pipe cleaner around a single curl in the slinky spring so that the rest of the spring can move easily.
2 Two people slowly stretch the spring out along the floor – slightly beyond its normal length. Allow the spring's movement to become still.
3 One person pushes their end of the spring firmly forwards, towards the other person, and then returns it to the rest position. This will create areas where the coils are pushed together (compressions) and areas where the coils are stretched out (rarefactions).

These areas will travel along the spring to the other end. The person at the other end needs to hold the spring firmly and still.
4 Try to make the wave have more or less energy by pushing the end faster, while keeping the length of the wave the same. This is the same as making a sound louder. Pushing less models a softer sound.
5 Try to change the frequency (number of waves per second) of your wave. Try to create 4 waves per second (a higher frequency) and 0.5 waves per second (a lower frequency).
6 Draw labelled diagrams of the waves you created, carefully indicating how the waves show that different frequencies have been achieved.

Questions

1 Describe how far the pipe cleaner moved as the wave moved along the spring.
2 Describe what happened when the wave reached the other end of the spring.
3 Compare (the similarities and differences between) the model wave bouncing back from a hard surface to an echo.
4 Describe how the model can be used to represent higher frequency sound waves.
5 Explain how the distance between the compressions is affected in lower frequency waves.

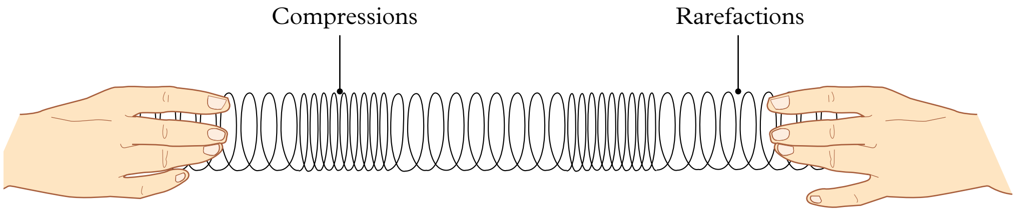


Figure 1 Experimental set-up

4.2A

The speed of sound

CHALLENGE

What you need

- Tape measure or trundle wheel
- Stopwatches
- ‘Slap sticks’ (or two large sticks that make a sound when hit together)

What to do

1. On the school oval, measure a distance of 100–200 m.
2. One person takes the slap sticks to the far end of the measured distance. When everyone is ready, slap the sticks together to make a noise.
3. The rest of the class should start their stopwatches when they see the sticks hit together, and stop them when they hear the ‘slap’.
4. Repeat this measurement five times.
5. Record your measurements in a table.

Questions

1. Explain why you need to repeat this measurement many times.
2. Calculate the average amount of time it took for sound to travel the measured distance.
3. To calculate the approximate speed of sound, use the formula:

$$\text{Speed} = \frac{\text{distance travelled (m)}}{\text{time (s)}}$$

4. Compare your measurement to the accepted value of 340 m/s. Explain any differences between the two measurements.

4.2B

Racing dominoes

CHALLENGE

What you need

- Large set of dominoes
- Metre ruler

What to do

1. Set up two rows of dominoes 1 m long on the floor (see Figure 1). One set of dominoes should be spaced far apart from each other (but still close enough to knock each other over) while the second set of dominoes are much closer together.
2. Use the metre ruler to knock over the first domino of each row at the same time.

Questions

1. Identify which row of falling dominoes reached the finish line first. Explain a possible reason for this result.
2. Compare the space between the dominoes in rows 1 and 2 to the space between the particles of liquids and gases.
3. Use the evidence from your model to identify whether sound will travel faster in gas or liquid.

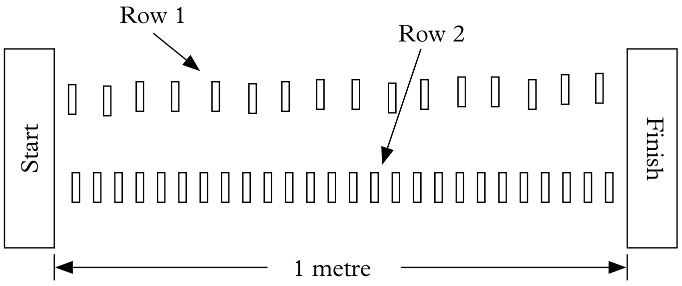


Figure 1 Experimental set-up

Figure 2 Fallen dominoes

4.3 Why do we need two ears?

EXPERIMENT

Aim

To investigate the advantage of having two ears.

Materials

- Chair
- Blindfold (optional)

Method

1 Work in groups of three. Allocate one person to be tested, one person to be the tester and one person to be the recorder.

2 The person being tested sits on the chair and closes his or her eyes (or is blindfolded) during the whole test.

3 The tester clicks his or her fingers approximately 1 m away from the ear of the person seated.

4 The tester makes the clicking sounds and the seated person points to where he or she thinks the sound came from.

5 The recorder writes down whether this is correct.

6 The tester tries a total of 10 different positions, including one from directly above the seated person's head and several in front of and behind the seated person.

7 Record the seated person's score out of 10.

8 Swap roles so that everyone has a turn at each role.

9 Repeat the experiment, with each person covering one ear with the palm of their hand.

Results

Record your observations in a table.

Discussion

1 Use your results to explain which system – two ears or one – is the more accurate way to locate a sound. (HINT: Use the numbers you recorded during the experiment.)

2 Compare the accuracy of detecting sound from in front of the ear to when sounds came from behind the ear. Use the shape of the ear to explain any differences.

3 Describe the accuracy of detecting sounds made directly above your head.

Conclusion

Explain the advantage of having two ears rather than one.

Figure 1 Experimental set-up

4.4 Is school bad for your health?

CHALLENGE

CAUTION! Never expose yourself to very loud noise or yell into someone's ear. When testing the volume of a classmate's yell, or any other loud sound, stand 1 m away from the source of the sound.

What you need

- 1 sound level meter per group
- Map of your school
- Metre ruler

What to do

Conduct a survey of the noise levels around your school.

1 Visit your allocated part of the school and measure the sound levels inside rooms and outside. (Make sure someone checks the library.)

2 When outside and far away from any classes, check the loudness levels of the individual voices in your group. First, speak as softly as possible and measure the sound level at 1 m. Then, measure a loud yell, again at a distance of 1 m. Collect these results for each person in the group.

Questions

1 Identify the average sound level of your group for a loud yell.

2 Describe why it is recommended you should not yell in someone's ear.

3 Find the average noise level in classrooms. Identify the room that was the noisiest.

4 List the noise levels of your school's classrooms from loudest to quietest.

4.5 Modelling light waves

CHALLENGE

What you need

- Slinky spring
- Clear space on the floor

What to do

1 Two people hold the spring, one at each end. On the floor, slowly stretch the spring out slightly beyond its normal length. One person flicks their end of the spring firmly to one side. This will create a sideways 'pulse' in the spring. The other person needs to hold the spring firmly and still. The pulse will travel along the spring to the other end (see Figure 1).

2 Continue flicking the spring to create a continuous transverse wave. Identify the peaks and troughs of the wave.

3 Make the wave have more or less energy by changing how hard you flick the end. Try to keep the speed of the wave the same.

4 Increase the number of waves per second. You have just modelled a wave of higher frequency.

5 Try to reduce the number of waves. This model represents a lower frequency wave.

6 Draw a labelled diagram of a high frequency wave and a low frequency wave. Identify the wavelength in each diagram.

Questions

1 Describe how you modelled higher frequencies with your model light waves.

2 Explain how increasing the frequency affects the distance between the peaks of the wave (wavelength).

3 Identify another example of a transverse wave that exists in the real world.

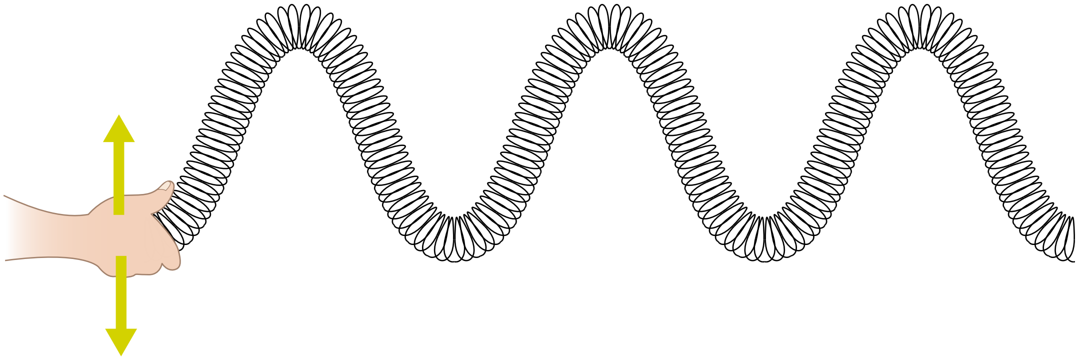


Figure 1 Flicking the slinky creates a pulse.

4.6A Using a Hodson light box

SKILLS LAB

What you need

- Hodson light box kit
- 2–12 V power supply
- Pencil

This six-step process outlines how to use a Hodson light box.

What to do

1 Place the light box on a piece of white A4 paper.

Figure 1 Setting up the light box

2 Plug the light box into either the AC or DC sockets of a 2–12 V power supply. The voltage dial controls the brightness of the light globe.

Figure 2 Turning on the light box

3 Slide a slot former into the opposite end of the light box to where the mirror flaps are. Usually a single-slot or a three-slot former is used.

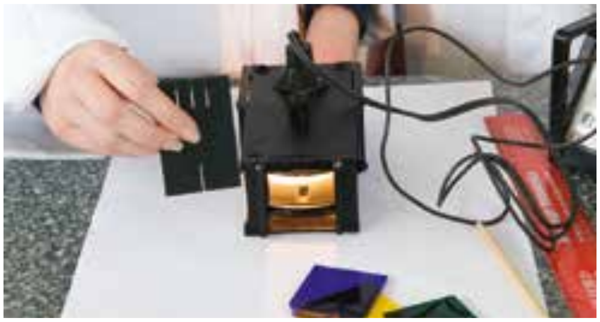


Figure 3 Sliding in a slot former

4 Aim the light ray at the target, in this case a plane mirror.

Figure 4 Aiming the light rays at a mirror

5 Use a sharp pencil to mark the incident and reflected rays with dots.

Figure 5 Marking the rays

6 Remove the light box and join the dots with thin, straight pencil lines.

Figure 6 Joining the dots

4.6B Reflection from plane mirrors

EXPERIMENT

Aim

To investigate the law of reflection: the angle of incidence equals the angle of reflection.

Materials

- Hodson light Blu-Tack
- 2–12 V power supply
- Sheet of white A4 paper
- Plane mirror from light box kit
- Blu-Tack
- Ruler
- Pencil
- Protractor

Method

1. Rule a straight line in pencil centrally across the width of the A4 paper. The mirror surface will be placed along this line.
2. Use the protractor to construct a normal line at 90° in the centre of the first line.
3. Position the back edge of the plane mirror along the first pencil line. Keep it in place with Blu-Tack.
4. Set up the Hodson light box, darken the room and aim a single incident ray at the centre of the mirror where the normal begins. Mark the position of the incident and reflected rays with pencil dots.
5. Move the light box to a different angle and aim another incident ray so that it hits the mirror at the same place as it did the first time. Mark the incidence and reflection rays by drawing arrows. Label the lines A.
6. Repeat step 5 until five sets of lines are obtained. Label each set of lines B, C, D, etc.

Results

1. Remove the light box and rule lines to show the straight path of the incident and reflected rays.
2. Carefully use the protractor to measure the five angles of incidence and the five angles of reflection for each set of lines A, B, C, etc.
3. Move the protractor so that the 0° of the protractor is along the normal. Read the angle between the normal and each incident ray, and between the normal and reflected rays.
4. Record your results in a suitable table.

Discussion

1. Explain why the back edge and not the front edge of the plane mirror should be lined up on the pencil line.
2. Compare your angles of incidence to your angles of reflection. Explain how they support the law of reflection.
3. List two possible sources of error in this experiment.
4. Describe what happened when you directed the light at right angles to the mirror.
5. Explain whether the law of reflection is still obeyed if the angle of incidence is 0°.
6. List at least three examples where you have observed the law of reflection in action.

Conclusion

Describe what you know about the relationship between the angle of incidence and the angle of reflection.

4.6C Mirror writing

CHALLENGE

What you need

- Large plane mirror
- Logbook/workbook
- Pencil

Figure 1 A backwards dog?

What to do

1 Hold a large plane mirror in front of your page in your logbook and try to write your name so that it is legible in the mirror. Practise with other words until you get good at this.

2 In some countries, ambulances have their name spelt backwards on the vehicle so drivers can see it in their rear-view mirror. See if you can work out how to write the word 'ambulance' backwards in capital letters so it would read correctly when viewed this way. Have a friend hold the word up behind you and hold the mirror up in front of your eyes.

3 Draw a short maze, then attempt to guide your pen through the maze by only looking in the mirror. A friend could cover the real maze so you are not tempted to look. Just look in the mirror.

Questions

1 Contrast the level of difficulty in the three activities.

2 Describe how practice will change the level of difficulty of these tasks.

3 Some people place a sticker with words on the back window of their car. Identify whether the words would appear as a mirror image or the 'right way round' in the rear vision mirror. Justify your answer by describing how you made your decision.

4.6D Using curved mirrors

CHALLENGE

What you need

- Convex mirror
- Concave mirror
- Pen
- Hodson light box
- 2–12 V power supply

What to do

1 Place an object, such as a pen tip, close to the convex mirror and observe the image. Try to describe the nature of the image.
   - Upright or inverted (upside down)?
   - Larger (magnified) or smaller (reduced) than the object?
   - Real (capable of being captured on a screen or piece of paper) or virtual?

2 Move the object further from the mirror and repeat your observations.

3 Repeat step 1 with a concave mirror. It is possible to form a real image with a concave mirror and there is more variation in the nature of the image as the object is moved further from the mirror.

4 Summarise your findings in a table that compares the two types of mirrors.

5 Use the Hodson light box kit to investigate curved mirrors. There should be a convex and concave mirror in the kit. Use the three-slot former in the kit to draw diagrams of the incident and reflect rays for both types of curved mirrors.

Questions

1 Identify the mirror that converges (brings together) the rays.

2 Identify the mirror that diverges (spreads apart) the light rays.

3 Describe how your appearance would change if you viewed your image in concave and convex mirrors.

4 Describe how a shop uses mirrors to make their clothes and clients look thinner.

4.7A Bending of light

EXPERIMENT

Aim

To investigate the path of light rays during the process of refraction.

Materials

- Hodson light box kit
- 2–12 V power supply
- Sheet of white A4 paper
- Perspex block from light box kit
- Blu-Tack
- Ruler
- Pencil
- Protractor

Method

1. Place the Perspex block in the centre of the A4 paper. Trace around the outside of the Perspex block with your pencil.
2. Remove the block and use the protractor to construct a normal at 90° to one of the long sides of the block.
3. Position the block on the paper again. Keep it in place with a thin amount of Blu-Tack.
4. Set up the Hodson light box, darken the room and aim a single incident ray at the face of the block at the normal line. Draw the incidence and reflection ray using arrows to identify each.
5. Move the light box so that the ray is aimed at the face of the block at an angle of approximately 45°. Mark the position of the incident ray and the ray that exits the block on the other side with pencil dots. Ignore any reflected rays at this time.
6. Remove the block and turn off the light box. Use a ruler to draw the straight rays that you identified.

Results

1. Join the end of the incident ray to where it exits the block on the other side. Construct a normal to the face of the block where the ray exits.
2. Use the protractor to measure the four angles on your diagram. Line up the 0° line of the protractor along the normal each time and read the angles between the normal and incident rays and between the normal and the refracted rays. Record your results in two tables for refraction from air to Perspex and refraction from Perspex to air.

Discussion

1. Explain your observation when the incident light travelled along the normal.
2. Compare your angles of incidence to your angles of refraction as the light entered the Perspex block. Explain your observation.
3. Compare the size of the angle at which the light hit the glass block with the angle at which it leaves.
4. Identify which medium is most dense (air or the Perspex block).
5. Describe how the light ray moved (towards or away from the normal) as it moved into the Perspex block, and as it leaves the Perspex block.
6. Compare your results to the expected refraction of light.
7. Identify two possible sources of error in this experiment.

Conclusion

Describe what you know about the path of light rays during the process of refraction.

4.7B Creating images with convex lenses

EXPERIMENT

Aim

To investigate the behaviour of a convex lens and the nature of the image produced at different object–lens distances.

Materials

- Hodson light box kit
- 2–12 V power supply
- Candle
- Heatproof mat
- Matches
- Convex lens
- Lens holder
- Rulers (30 cm, 1 m)
- White paper screen
- Blu-Tack

Method

1. Determine the focal length of the lens by placing the lens on a piece of paper and shining three rays of light through it so the light converges into a single focal point. Measure the distance from the centre of the lens to the focal point. This is the focal length *f*. Double the focal length. This is called 2*f*.
2. Place the candle on the heatproof mat and light the candle. Mount the lens in the lens holder and check to see if the centre of the lens is in line with the candle flame. If not, raise it to the correct height.
3. Darken the room and position the lens at a distance of more than twice the focal length from the candle flame (the object). Try to capture an image on the paper screen by moving the screen slowly until a focused image of the candle is formed. Describe the size of the image compared to the object (magnified, same size or reduced), the type of image (real or virtual) and the orientation of the image (inverted or upright).
4. Move the lens closer to the candle so that the object–lens distance is between *f* and 2*f*. Repeat your observations.
5. Repeat for the other lens positions in Table 1. In some cases, the image may not form on the screen. Instead, it can be found by looking into the lens towards the candle flame. This will be a virtual image. In one case, there may be no image – real or virtual.

Results

Complete Table 1.

Discussion

1. Describe when the lens produced a real image and when it produced a virtual image.
2. Explain any other observations you made or ask your teacher about them.
3. Compare your results with those of other members of the class.
4. Identify one way you could improve your method to produce more reliable results.

Conclusion

Describe what you know about the behaviour of a convex lens and the images it produces.

Table 1 Convex lens experiment results

Object–lens distance	Size of image	Type of image	Orientation of image	Any other observations
Larger than 2f				
Equal to 2f				
Between f and 2f				
Equal to f				
Less than f				

4.8 What colour is it?

EXPERIMENT

Aim

To investigate the addition of coloured light and explore the behaviour of coloured filters.

Materials

- Hodson light box kit
- 2–12 V power supply
- Sheet of white paper

Method

1 Connect the light box to a 2–12 V power supply and place it on the sheet of paper.

2 Place the three primary filters (red, green and blue) in each of the three separate slotted sections in the light box. Adjust the mirror flaps so that the colours can overlap on the paper. Change the combination of filters and copy and complete Table 1.

Table 1 Experiment 1 results

Addition of primary colours	Colour produced
Red + green + blue	
Red + blue	
Green + blue	
Red + green	

3 Replace one of the primary filters with the secondary filters (yellow, cyan and magenta) and copy and complete Table 2.

Table 2 Experiment 2 results

Addition of colours	Colour produced
Yellow (side slot) + blue (front slot)	
Magenta (side slot) + green (front slot)	
Cyan (side slot) + red (front slot)	

4 Switch off the light box and remove the filters. Select a red, green, blue and yellow oblique surface from the light box kit. Hold each of the coloured surfaces against the back of each primary filter. Record in Table 3 the colour that each surface appears.

Table 3 Experiment 3 results

	Colour surface appears when viewed through:		
Surface colour	Red filter	Green filter	Blue filter
Red			
Green			
Blue			
Yellow			

Discussion

1 Identify the combinations of colours that produce white light.

2 Describe any patterns you observed in each of the tables. Explain the patterns you observed.

3 Identify one possible source of error in the experiment.

4 Describe the difficulties you had, and how you overcame them.

Conclusion

Describe what you know about what happens when coloured lights are added to each other.

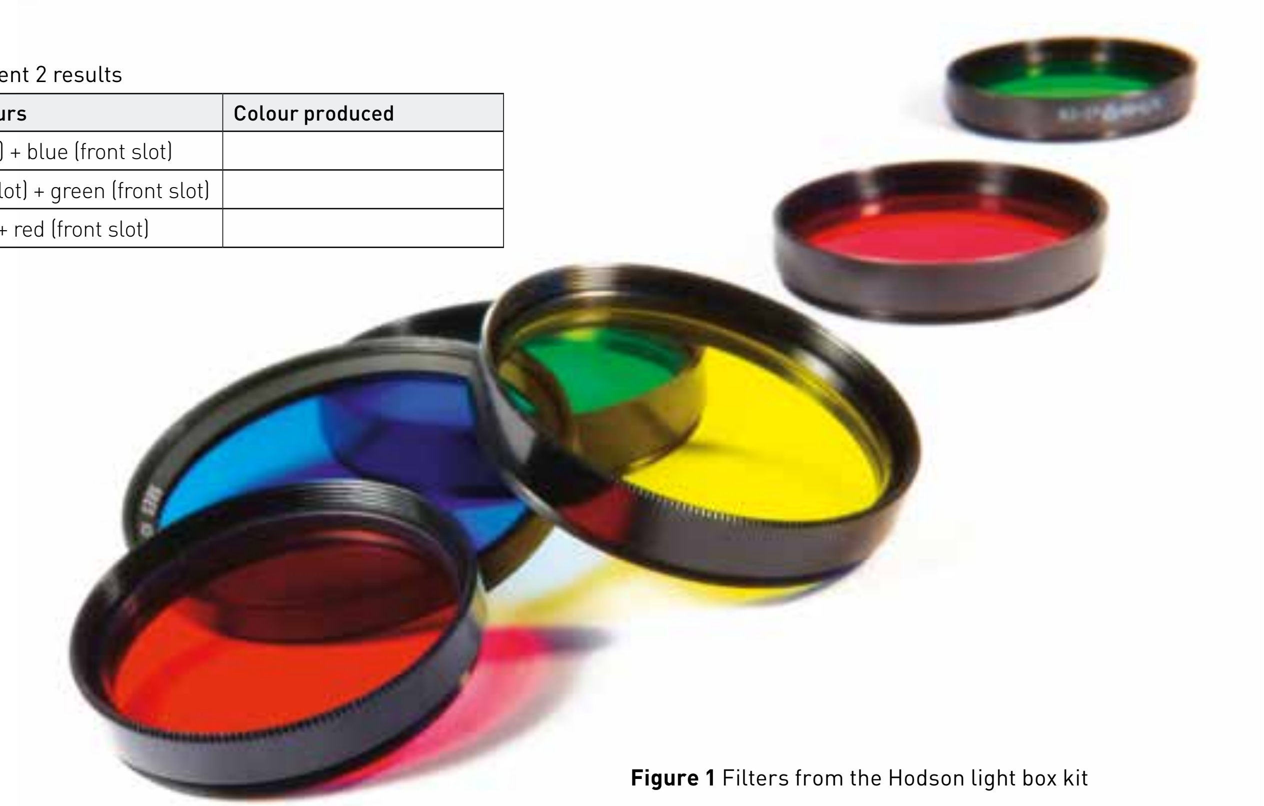


Figure 1 Filters from the Hodson light box kit

4.9 What is the wavelength of a microwave?

EXPERIMENT

CAUTION! Some students might have egg allergies.

Aim

To determine the wavelength of a microwave.

Materials

- Microwave oven with the turntable removed
- Large flat plate at least 20 cm in diameter (safe for use in a microwave)
- Oven mitts
- Egg white
- Ruler
- Black cardboard
- Spatula or spoon

Background

A microwave oven uses electromagnetic waves to heat food. These waves move through the cooking area in a set fashion. All microwave ovens have turntables to rotate food so that it cooks evenly. This is because of the wavelike motion of the energy. Without the turntable, the energy is focused in fixed parts of the oven.

You can use this to determine the wavelength of the microwaves in your microwave oven.

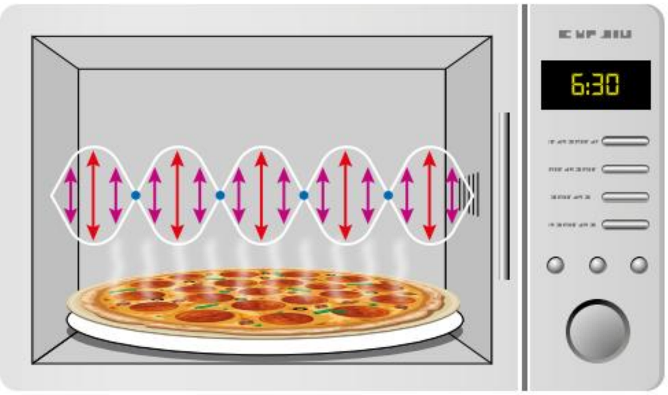


Figure 1 A microwave oven uses electromagnetic waves to heat food.

Figure 2 A microwave oven with both the rotating platter and drive mechanism removed.

Method

1 Crack the egg and separate the egg white from the egg yolk.
2 Spread the egg white evenly over the black paper.
3 Place the paper on the plate in the oven and turn on for 15–30 seconds (depending on the power of the microwave). The egg should start cooking in stripes/patches.
4 Remove the plate from the microwave and identify the centre of the cooked stripes/patches. Measure the distance between two of the cooked patches.
5 Repeat this experiment several times and determine an average distance between the cooked egg white.

Figure 3 Using the cooked portions of the egg white to measure the distance between 'hot spots' in the microwave oven

Results

1 Record all your observations in a table.
2 Multiply the average distance between the cooked egg white by 2 to determine the length of a full wavelength.

Discussion

1 Identify the wavelength of the microwaves in your microwave oven.
2 Describe any difficulty you had when determining the centre of the cooked portion of egg. Calculate the error margin of your calculation (± the width of the cooked egg bands).
3 Explain why you needed to repeat your experiment several times.

Conclusion

Explain what you know about the wavelength of microwaves.

4.10A Eye dissection

EXPERIMENT

CAUTION! Wear your lab coat, safety goggles and gloves. Be careful with the scalpel because it is likely to be very sharp. When cutting, keep clear of hands and other people.

Aim

To examine the structure of the eye and consider how the various components work separately and together.

Materials

- Animal eyeball (fresh cow eyes are best)
- Dissecting board
- Scalpel
- Scissors
- Forceps
- Newspaper

Method

1 With the forceps and the scalpel or scissors, carefully remove the fatty tissue from around the eyeball.

Figure 1 Step 1

2 Look for the optic nerve. It should look like a thick strand coming from the back of the eyeball.

Figure 2 Step 2

3 Rotate the eyeball until the pupil is facing you. Notice the tough white outer coating extending over much of the eye.

4 Observe that in front of the eye the coating is transparent. Note that this transparent portion of the sclera is more sharply curved than the rest of the coating.

5 Use the scalpel to make a small cut on the side of the eye, then use the scissors to carefully cut the eye into two equal parts, front and rear. Taking care not to squeeze the eyeball, cut all the way around the eyeball until the two halves can be separated.

Figure 3 Step 5

6 Carefully separate the lens from the rest of the eye by slicing through the fine muscles; then put it on a piece of newspaper. The lens is colourless and transparent in life, but it is usually white in preserved specimens.

Figure 4 Step 6

7 Pick up the lens with your forceps and move it about above the newspaper print as you look down on it. Squeeze the lens from the side as you look down through it. Note what you observe.
8 Examine the rear half of the eyeball and notice the black/pearly inside layer.
9 Examine the back of the front part of the eye from which you earlier took the lens. The iris, the muscular ring-like structure surrounding the pupil, is now exposed.

Figure 5 Step 9

10 Leave your gloves on until you have finished the experiment. All dissecting equipment must be washed. All parts of the eye must be wrapped in newspaper and placed in the special bag provided. Disinfect your workspace and, finally, wash your hands thoroughly.

Results

Include labelled diagrams and observations in your results.

Discussion

1 Describe the function of the muscles attached to the outside of the eyeball.
2 Describe the function of the optic nerve.
3 Identify the name of the white outer coating of the eye.
4 Identify the name of the transparent part of the sclera.
5 Identify the name and function of the watery-like substance in the eyeball.
6 The space between the cornea and the lens is also filled with a colourless, transparent, watery fluid. Identify the name of this fluid.
7 Identify the shape of the lens as convex or concave.
8 Identify the name and function of the black/pearly inside layer of the eye.
9 Identify the function of the iris.

Conclusion

Describe what you know about the structure and function of the eye.

4.10B Vision tests

CHALLENGE

PART A: NEAR POINT OF VISION

The closer an object is to the eye, the thicker the lens needs to be. However, there is a limit to how much the lens can change shape and at very close distances the lens cannot clearly focus on an object. The distance from the eye to the nearest point that can be focused clearly (minimum focal length) is called the **near point of vision**.

What you need

- Ruler
- Sheet of A4 paper
- Pencil

What to do

Work in pairs.

1 Hold a pencil at arm's length, with the tip of the pencil upright.

2 Place a hand over your left eye.

3 Focus your right eye on the tip of the pencil.

4 Slowly bring the pencil closer to your eye until the tip becomes blurred.

5 Hold the pencil in this position and ask your partner to measure the distance from your eye to the tip of the pencil with the ruler.

6 Repeat the steps to find the near point for your left eye, then swap with your partner.

Questions

1 Compare the near point of your left eye with the near point of your right eye.

2 Compare your partner's near points with yours.

PART B: TESTING BINOCULAR VISION

What you need

- Sheet of A4 paper

What to do

1 Roll the sheet of A4 paper into a tube of 3–4 cm diameter and hold it up to one eye so that only the view through the tube can be seen.

2 With the other eye, look at your hand, palm open, held alongside the end of the tube. Keep both eyes open.

Questions

1 Describe what you 'see' when both eyes are open.

2 Explain your observations.

PART C: FINDING THE DOMINANT EYE

What you need

- Sheet of A4 paper
- Scissors
- Ruler

What to do

1 Cut a triangle out of the sheet of A4 paper with sides of 3–4 cm. Hold it at arm's length in front of your eyes. Look past it with both eyes and focus on an object on the other side of the room.

2 Keeping the triangle steady, close one eye, open it and then close the other eye. The object will appear to move the most when the non-dominant eye closes.

Questions

1 Describe what happened when you closed each eye.

2 Identify your dominant eye (right or left).

PART D: JUDGING DISTANCES

What to do

1 Hold your arms outstretched to the side and at shoulder height, with elbows slightly bent and just your index fingers pointing.

2 Keeping both eyes open, try to make your fingertips meet in front of you.

3 Repeat this procedure with one eye closed. Repeat for the other eye.

Questions

1 Compare your ability to judge distances with one eye open to when you had two eyes open.

2 Explain the differences you observed in your ability to judge distances.

PART E: FINDING YOUR BLIND SPOT

What you need

- Sheet of A4 paper

What to do

1 On the piece of paper, draw a dot and a cross in line with each other but about 7 cm apart.

2 Hold the paper approximately 15 cm from your eyes.

3 Close your right eye and concentrate on the cross with your left eye.

4 Slowly move the paper away from you until the dot disappears from your vision.

Questions

1 Explain why the dot disappears.

2 Explain why the dot does not disappear if both eyes are kept open.

4.11 Make a jelly lens for your smartphone

CHALLENGE

Design brief

To make a jelly lens for a smartphone.

What you need

- Gelatine powder (no colours or flavours)
- Petri dish
- Boiling water
- Small beaker
- Measuring spoons
- Dropper
- Electric jug

What to do

1 Add 2 teaspoons of boiling water to one of the small beakers.

2 Add a quarter of a teaspoon of gelatine to the water and stir it for 4 minutes until it starts to thicken.

3 Use the dropper to place 1 drop of the mixture on the underside of a Petri dish.

4 After 5 seconds, turn the Petri dish over so that the drop of gelatine hangs down. The drop will form a parabolic shape without dripping off the Petri dish.

5 Let the jelly set for 15 minutes.

6 Repeat steps 3–5 several times so that the best lens can be used.

7 Gently lift off the gelatine drop and place it over the lens of your smart phone.

8 Try taking close-up photos of things using your lens. When finished, remove the gelatine lens and carefully wipe the phone clean with damp (not wet) tissue paper; then dry the lens with dry tissue paper.

Questions

1 Identify how far away the phone needed to be to focus without the gelatine lens.

2 Describe how far away the phone needed to be to focus with the gelatine lens.

3 Explain how the lens changed the light moving into the phone. (Use terms such as ‘refraction’, ‘convex’ and ‘converge’.)

Figure 1 Jelly

5.1A Classifying elements

CHALLENGE

Design brief

To make a set of element cards.

What you need

- Cardboard
- Felt-tipped pens
- Scissors

What to do

1. Make up some cards like the ones shown in Figure 1 to represent the different elements.
2. Sort the cards into those with a one-letter symbol and those with a two-letter symbol.
   - Identify the number of elements that have a one-letter symbol.
   - Identify the number of elements that have a two-letter symbol.
   - Explain why classifying elements according to their symbol is a bad idea.
3. Sort the cards according to the colour of the element.
   - Identify the number of elements that are silver.
   - Identify the number of elements that have another colour.
   - Explain why classifying elements according to their colour is a bad idea.
4. Sort the cards according to whether they are solids, liquids or gases.
   - Identify the number of elements that are solids, liquids or gases.
   - Explain why classifying elements according to their state is a bad idea.

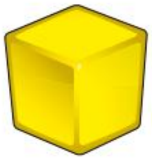
Cu **Copper** Solid brown, shiny 	**Al** **Aluminium** Solid silver, shiny 	**Mg** **Magnesium** Solid silver, shiny 	**Cl** **Chlorine** Gas yellowish-green 	**C** **Carbon** Solid black, dull 	**S** **Sulfur** Solid yellow, dull 
Fe **Iron** Solid grey, shiny 	**P** **Phosphorus** Solid red, dull 	**Pb** **Lead** Solid grey, shiny 	**K** **Potassium** Solid silver, shiny 	**Hg** **Mercury** Liquid silver, shiny 	**O** **Oxygen** Gas colourless 
H **Hydrogen** Gas colourless 	**I** **Iodine** Solid grey, sparkly 	**Ca** **Calcium** Solid grey, shiny 	**Sn** **Tin** Solid silver, shiny 	**Br** **Bromine** Liquid red-brown 	**Zn** **Zinc** Solid silver, shiny 

Figure 1 Example element cards

5.1B Identifying the elements in the periodic table

CHALLENGE

What you need

- A copy of the periodic table
- Coloured pencils

What to do

1. On your periodic table:
   - Draw a triangle around all the elements that are liquids.
   - Draw a circle around all the gases.
   - Draw a square around all the metalloids.
   - Colour all the transition metals in blue.
2. Choose one element on the table.
   - Colour your element in green.
   - Colour the period that your element belongs to in red.
   - Colour the group your element belongs to in yellow.
3. Investigate the following information for your element:
   - name
   - symbol
   - atomic number
   - atomic mass
   - five properties of your element
   - some uses for your element
   - where your element can be found
   - who discovered your element.
4. Identify whether your element is considered dangerous. A Safety Data Sheet (SDS) is provided for every dangerous substance. It contains information about the risks involved in handling the substance. Investigate a SDS for your chosen element and record the following information:
   - risks associated with your element
   - how to handle your element safely.

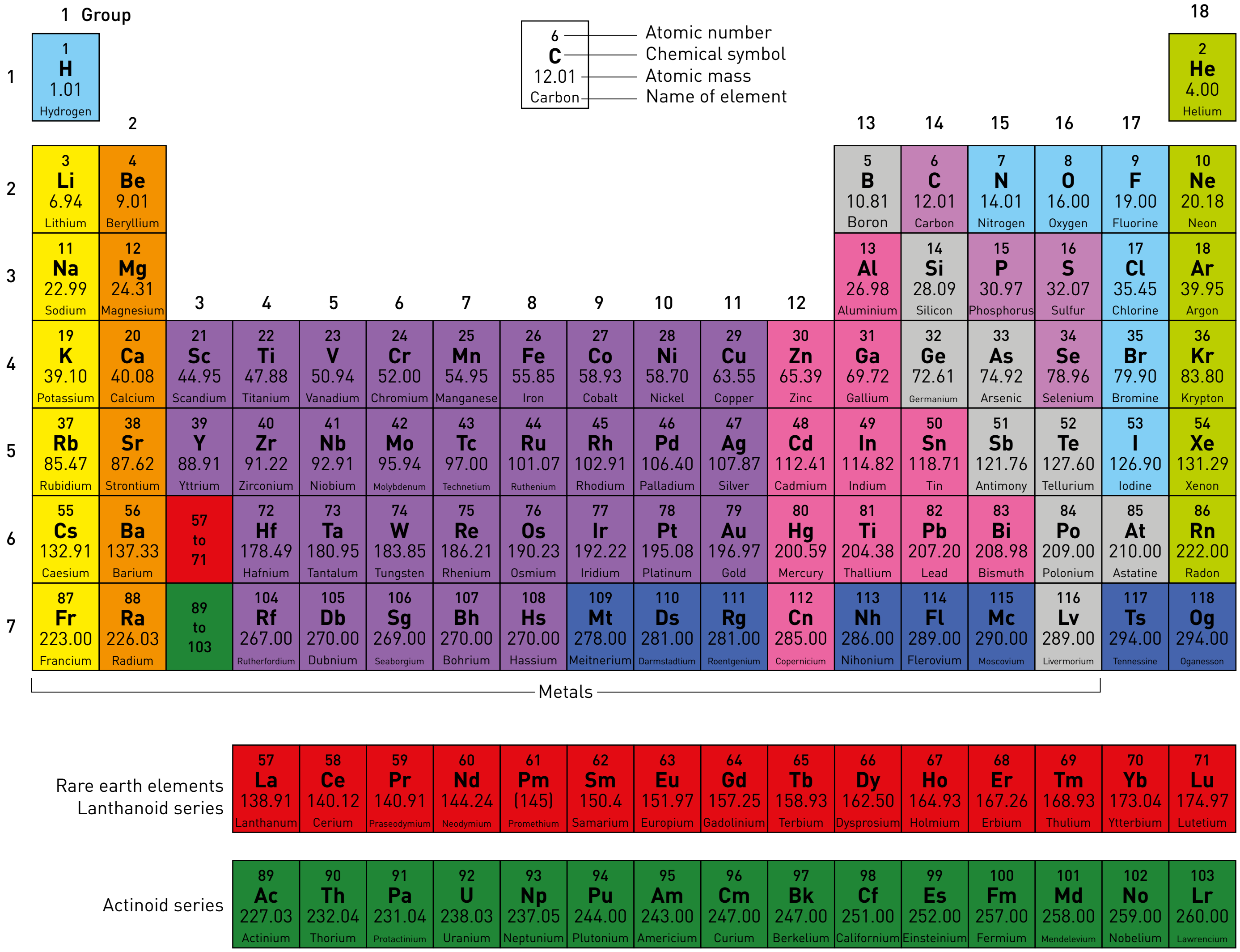


Figure 1 The periodic table

5.1C Properties of the elements

EXPERIMENT

Aim

To observe the differences between different elements of the periodic table.

Materials

- Steel wool
- Aluminium metal strips
- Copper metal strips
- Magnesium metal strips
- Graphite/lead pencil
- Zinc metal strips
- Iron nail (non-galvanised)
- Forceps
- Battery
- 3 wires
- Lamp
- 0.5 M hydrochloric acid
- Deionised/distilled water
- 6 test tubes
- Test tube holder

Method

1. Use the steel wool to rub a small section of your material. Record the colour and appearance (dull or shiny) in Table 1.
2. Use the forceps to try to bend each substance. Identify whether it is malleable (able to bend) of brittle (breaks when bent). Record this in Table 1.
3. Set up a circuit with the battery, lamp and wires as shown below. Connect the two loose wires to the material. Identify whether the light glows. Explain whether your material conducts electricity.
4. Place your sample into a test tube and add 3 cm of 0.5 M (dilute) hydrochloric acid to the test tube. Describe any reactions that you observe. If possible, leave it overnight to see if there is any change.
5. Repeat your tests with all of your samples and record your observations in Table 1.

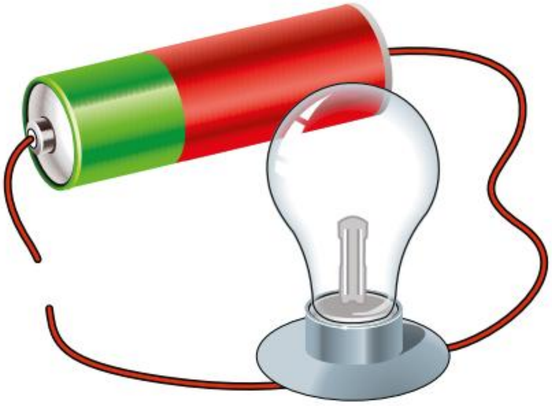


Figure 1 This incomplete circuit can measure the conductivity of objects.

Results

Record your results in Table 1.

Discussion

1. Compare your observations of the elements you tested.
2. Use your results to divide all the materials into two groups. Describe the properties you used to separate the materials.
3. If you discovered a new material that was shiny and that bent when you dropped it, explain which group you would put it in.

Conclusion

Describe what you know about the physical and chemical properties of these materials.

Table 1 Materials and their properties

Element	Is it shiny/ dull?	Is it malleable/ brittle?	Does it conduct electricity?	Does it react with acid?

Figure 2 Steel wool

5.2 Decomposing copper carbonate

EXPERIMENT

Aim

To decompose (break into smaller parts) copper carbonate.

Materials

- Plastic beaker
- Test tube or crucible
- Electronic balance
- Spatula
- Copper carbonate
- Bunsen burner
- Heatproof mat
- Tripod stand
- Matches
- Wooden tongs
- Paper towel

Safety

CAUTION! Wear safety glasses and lab coat, and tie long hair back when using a Bunsen burner.

- Use a yellow (cooler) safety flame for this experiment.
- Hold the test tube or crucible securely with the tongs and always point it away from yourself and others.
- Never place hot objects on the balance.

Method

1 Place a plastic beaker containing the test tube on the balance. Use the 'Tare' button to return the reading to zero.

2 Using a spatula, add approximately 3 g of copper carbonate into the test tube. Record the mass in grams (this is W1).

3 Set the Bunsen burner up on the heatproof mat. Light the flame, ensuring the hole is closed and a yellow (safety) flame is burning.

4 Using the wooden tongs to hold the top of the test tube, gently wave the base of the test tube over the flame twice. Record any changes. Continue to do this for 2 minutes, recording any changes. Be very careful to point the open end of the test tube away from others and yourself.

5 Allow the test tube and copper carbonate to cool. Wipe off any black powder from the outside of the tube with paper towel.

6 Place the test tube in the original plastic beaker. Reweigh the test tube and beaker and record the mass in grams (this is W2). Note any change in weight.

Results

Record your results in Table 1.

Discussion

1 Describe what happened to the copper carbonate. Consider the colour and any change in mass.

2 Describe the evidence that copper carbonate is a compound and not an element.

3 Describe one possible source of error in this experiment.

Conclusion

Describe what happens when copper carbonate decomposes.

Table 1 Copper carbonate before and after heating

Weight of copper carbonate before heating (W1) (g)	Weight of copper carbonate after heating (W2) (g)	Difference W1–W2 (g)

Figure 1 Matches are used to light the Bunsen burner flame.

5.3A Melting chocolate

EXPERIMENT

Aim

To examine the physical change in melting chocolate.

Materials

- Milk, dark and white cooking chocolate buttons (approximately 10 of each)
- 3 × 100 mL beakers
- Thermometer
- 250 mL beaker (as a water bath)
- Stirring rod
- Bunsen burner and heatproof mat or hotplate
- Timer
- Matches
- Heatproof gloves

Method

1 Place 4 to 6 buttons of milk cooking chocolate in a beaker.
2 Place a thermometer in the beaker.
3 Place the beaker in a hot water bath (or boiling water in a beaker) and heat it to 60°C. Do not stir the chocolate.
4 Time how long it takes to melt. Record your observations.

Inquiry: What if another type of chocolate was melted? Would it melt faster or slower than milk chocolate?

- Write a prediction or hypothesis for your inquiry.
- Identify the (independent) variable that you will change from the first method.
- Identify the (dependent) variable that you will measure and/or observe.
- Identify two variables that you will need to control to ensure a fair test. Describe how you will control these variables.
- Write in your logbook the method you will use to complete your investigation.
- Draw a table to record your results.
- Show your teacher your planning (for approval) before starting your experiment.

Results

1 Record your observations, including any diagrams and photographs.
2 Draw a column graph of the time it took for each type of chocolate to melt.

Figure 1 Placing the small beaker of chocolate buttons in a beaker of boiling water causes the chocolate to melt.

Discussion

1 Contrast the difference in the time it took for each type of chocolate to melt.
2 Compare the pattern of melting for all three types of chocolate melt. (Inside first or outside edges first?)
3 Describe how a chef could apply your observations in the kitchen.
4 Describe any discolouration or burning of the chocolate that occurred.
5 Identify whether a new substance formed if the chocolate burnt.

Conclusion

Compare the properties of the milk, dark and white chocolate.

Figure 2 Chocolate buttons can be melted.

5.3B Exploring physical changes

CHALLENGE

What you need

- Aluminium drink can
- Elastic/rubber band
- Rock salt
- Ice
- Sugar cube
- Vitamin C tablet
- Slice of bread
- Piece of cloth
- Scissors

What to do

1. For each of the materials provided, find ways to change its physical appearance.
2. Record the method you used and your observations in Table 1.

Questions

1. Identify three different ways in which a physical change can take place.
2. Describe what each change has in common.

Table 1 Physical changes in materials

Material	Method used	Has the substance changed?	Can the change be reversed/undone?

Figure 1 Rock salt

5.4A Making caramel

CHALLENGE

What you need

- Sugar
- Test tube
- Test tube holder
- Bunsen burner and heatproof mat
- Matches

What to do

1. Place a pea-sized amount of ordinary sugar into a dry test tube.
2. Wearing safety glasses and, with the test tube facing away from you and everyone else, gently heat the sugar by passing it through the top part of a blue flame.
3. If you are careful, the sugar grains will crumble (they lose water in a chemical reaction) and turn into a brown syrup. This brown syrup is caramel. You may see condensation on the inside of the test tube as the water is driven out of the sugar.
4. If you continue heating, or heat too strongly, you will burn the sugar.

Questions

1. Describe the evidence that a chemical reaction has occurred at step 3.
2. Describe the chemical change that could occur if you continued heating the caramel in step 4.

Figure 1 Heated sugar undergoes a chemical change.

5.4B Observing chemical reactions

EXPERIMENT

Aim

To observe the reactants and products in different chemical reactions.

Materials

- Spatula
- Copper carbonate (solid)
- Bunsen burner
- Heatproof mat
- Matches
- 2 test tubes and a test tube holder
- Baking soda (sodium bicarbonate)
- 5 mL of 1 M hydrochloric acid
- Thermometer
- Wooden splint
- Magnesium ribbon (1 cm length)
- ~0.5 M copper sulfate solution
- 100 mL beaker
- Tongs
- Piece of steel wool, about thumb size when rolled up

Method

Part A

1 Place a large spatula of copper carbonate in a test tube.

2 Set up the Bunsen burner on the heatproof mat.

3 Using a test tube holder, gently heat the test tube by passing it over the flame twice. Make sure the test tube is facing away from you and everyone else. Observe any changes and repeat until the powder changes colour.

4 Collect the waste powder in a beaker for disposal.

Part B

1 Place the baking soda in a test tube to a depth of 0.5 cm.

2 Add an equal amount of 1 M hydrochloric acid to the test tube and observe.

3 Conduct a carbon dioxide test by holding a burning wood splint above the tube. If the flame goes out, carbon dioxide is present as one of the products of the chemical reaction.

Part C

1 Pour 5 mL of hydrochloric acid into the bottom of a test tube. Measure its temperature with the thermometer.

2 Add the magnesium ribbon to the test tube. Measure its temperature again.

3 Observe what happens using sight, touch (the outside of the tube only!) and sound.

Part D

1 Pour approximately 30 mL of the copper sulfate solution into a 100 mL beaker.

2 Use the tongs to place the steel wool into the copper sulfate solution.

3 Carefully observe the changes that occur to both the steel wool and the copper sulfate solution.

4 Collect the copper sulfate/steel wool solution in a beaker for safe disposal.

Figure 1 When heating a test tube, be sure to point it away from you or anyone else close by.

Results

Include your observations here.

Discussion

1 Describe what happened to the copper carbonate when it was heated.

2 Describe your observations of the copper carbonate when it was taken away from the heat.

3 Compare the copper carbonate experiment with the melting chocolate experiment.

4 Identify what is produced in the baking soda and acid experiment.

5 Explain why the flame on the burning splint goes out if carbon dioxide is present.

6 Explain what happened to the magnesium metal.

Conclusion

Explain what you observed about the reactants and products of chemical reactions.

5.5 Comparing reactants and products

EXPERIMENT

Aim

To examine the physical and chemical properties of reactants and products.

Materials

- Piece of magnesium ribbon (1 cm)
- 1 pea-sized sample of magnesium oxide powder
- 20 mL of 1 M hydrochloric acid
- 2 test tubes and test tube rack
- 10 mL measuring cylinder

Method

1 Place two test tubes in a test tube rack. Label one test tube Mg (magnesium) and the other MgO (magnesium oxide).

2 Add the samples (magnesium ribbon and oxide powder) to the appropriate test tubes.

3 Examine each sample by looking and carefully moving the sample in the bottom of the appropriate test tube. Record your observations in Table 1.

4 Add 10 mL of 1 M hydrochloric acid into each test tube in the test tube rack.

5 Observe any reactions. Record your observations in Table 1.

Results

Write a short statement describing each sample and how it reacted with acid.

Discussion

1 Compare the physical properties of magnesium and magnesium oxide.

2 Compare the chemical properties of magnesium and magnesium oxide.

Conclusion

Explain what you know about the physical and chemical properties of reactants and products.

Table 1 The properties of magnesium and magnesium oxide

Substance	Colour	State	Shiny/Dull	Reaction with acid
Magnesium				
Magnesium oxide				

Figure 1 Magnesium ribbon reacting with hydrochloric acid

5.6A Effect of particle size on reaction rates

EXPERIMENT

Aim

To observe how particle size affects the rate of a reaction.

Materials

- 2 small pieces of marble
- Mortar and pestle
- Electronic balance
- Pieces of filter paper
- 2 small beakers
- 10 mL graduated cylinder
- Dilute hydrochloric acid (1 M HCl)
- Stirring rod
- Stopwatch

Method

1 Place a piece of filter paper on the electronic balance and record the mass.

2 Place a small piece of marble onto the filter paper. Measure and record the combined mass.

3 Place the marble piece into a beaker and add 5.0 mL of hydrochloric acid. Record the time.

4 Stir the marble and the acid occasionally.

5 Time how long it takes for the reaction (gas bubbles being produced and the marble piece becoming smaller) to stop.

6 When the reaction stops, filter the remaining solution using the original filter paper.

7 Allow the filter paper to dry overnight and measure the mass.

8 Now select a piece of marble the same size as the first. Grind the marble piece into a fine powder using the mortar and pestle.

9 Place another piece of filter paper onto the electronic balance and record the mass. Place the ground-up marble onto the filter paper. Measure and record the combined mass.

Figure 1 Weighing the marble allows you to calculate the mass lost in the reaction.

Figure 2 Grinding the marble creates smaller particles.

10 Place the ground-up marble into a small beaker and add 5.0 mL of 1 M HCl. Record the time.

11 Stir the marble and the acid occasionally.

12 Time how long it takes for the reaction to stop.

13 When the reactions stops, filter the remaining solution using the original filter paper.

14 Allow the filter paper to dry overnight and measure the mass.

15 Calculate the mass lost in the first reaction by subtracting the mass of the filter paper after the reaction from the combined starting mass.

16 Calculate the percentage of calcium carbonate in the marble using the formula below.

$$\frac{\text{Mass lost in the first reaction}}{\text{Starting mass of marble in the first reaction}} \times \frac{100}{1}$$

17 Repeat these calculations for the ground-up marble.

Results

Draw an appropriate table for your results.

Discussion

1 Identify which type of marble dissolved faster (large chip or ground powder).

2 Explain why small pieces of marble react faster than one large piece.

3 Explain why stirring is necessary.

4 Explain if grinding up the marble changed the amount of calcium carbonate in the sample.

Conclusion

Explain what you know about how particle size affects reaction rate.

5.6B Speeding up reactions with enzymes

EXPERIMENT

Aim

To investigate the effect of enzymes on breaking down hydrogen peroxide.

Materials

- 1 packet of dried yeast
- 200 mL beaker
- 10 mL hydrogen peroxide (3%)
- Wooden splint
- Matches

Hydrogen peroxide breaks down into oxygen and water slowly over time. Yeast has a catalyst that speeds up this reaction.

Method

1. Add the yeast into the beaker.
2. Add 10 mL of the hydrogen peroxide into the beaker.
3. Light the splint and then blow it out. Place the glowing splint in the top half of the beaker.
4. Record your observations.

Results

Record your observations in a table.

Discussion

1. Describe whether the breakdown of hydrogen peroxide into oxygen and water was noticeable before the yeast was added.
2. Describe what happened to the rate of hydrogen peroxide breakdown when the yeast was added.
3. Describe the effect the gas produced had on the glowing splint.
4. Identify the gas that would cause this reaction.

Conclusion

Explain what you know about how enzymes affect the rate of a reaction.

Figure 1 Yeast in action

5.7 Making casein glue

EXPERIMENT

Background

Casein is a protein in milk. It can be extracted from milk and chemically changed so it has the properties of a glue.

Aim

To improve the manufacture of casein glue.

Materials

- Full cream milk (70 mL for each group of students)
- 250 mL beaker
- Bunsen burner
- Heatproof mat
- Tripod stand and gauze mat
- Matches
- Thermometer
- Heatproof glove
- Vinegar (20 mL)
- Stirring rod
- Sieve
- Disposable cleaning cloth
- 15 mL warm water
- ½ teaspoon baking powder
- Icy pole sticks (for gluing together)

Method

1. Pour 70 mL of milk into the 250 mL beaker.
2. Set up your Bunsen burner on the heatproof mat and heat the milk to *no more than 50°C*. Use a heatproof glove to remove the milk from the heat.
3. Slowly add 20 mL of vinegar to the milk, stirring gently. Do not stir vigorously as you will break up the curd (lumpy bits) being formed. The curd should clump as much as possible.
4. Set up the sieve over the sink or a large beaker. Put a piece of disposable cloth over the sieve.
5. Gently pour the mixture through the cloth and sieve to filter the whey (liquid) from the curds (lumps of mainly protein). Once it has stopped dripping, very gently squeeze the cloth to remove any excess liquid.
6. Return the solids to the original 250 mL beaker and crush the curds with a glass stirring rod to break them up as much as possible.
7. Add 15 mL of warm water and stir until it has an even consistency. Add ½ teaspoon of baking powder.
8. Take your sample and two icy pole sticks to your bench.
9. Spread your sample between the sticks and press them together. Leave them overnight and then test how well your glue has worked.

Inquiry: Choose one of the questions below to investigate.

- What if skim milk was used?
- What if soy milk was used?
- What if more vinegar was used?
- What if more baking powder was added?

Complete the following activities in relation to your inquiry.

- Write a prediction or hypothesis for your inquiry.
- Identify the (independent) variable that you will change from the first method.
- Identify the (dependent) variable that you will measure and/or observe.
- Identify two variables that you will need to control to ensure a fair test. Describe how you will control these variables.
- Write in your logbook the method you will use to complete your investigation.
- Draw a table to record your results.
- Show your teacher your planning (for approval) before starting your experiment.

Results

Record your observations and measurements in a table.

Discussion

1. Explain why it is important to wear safety glasses in this experiment.
2. Identify the reactants and products in this experiment.
3. Describe how you could compare the strength of different glues.

Conclusion

Describe what you know about making glue.

Figure 1 Icy pole sticks aplenty

6.1 Drawing cells

SKILLS LAB

What you need

- Microscopes
- Prepared slides
- Pencil and paper for drawings
- Several stations set up around the laboratory with microscopes adjusted to show different kinds of cells

CAUTION! Do not attempt to adjust any of the microscopes. Ask your teacher or laboratory technician to adjust the microscope if you think it has been bumped or has gone out of focus.

What to do

1. Look carefully at each specimen. Write down its name and a sentence that describes what you see.
2. Make a very simple pencil sketch of a single cell that you can see. Draw the outside edge of the cell first, including any bump or unusual shape you notice.
3. Draw two more cells that are close to your original cell. (Do not attempt to draw every cell that you see.)
4. If you can see anything inside the cells (it may only be a dark dot), mark this on your sketch.
5. Label any parts that you can identify.

Questions

1. Identify and describe the cell which, in your opinion, was the most unusual.
2. Identify the cells that had walls around them.
3. Identify the cell which was the smallest.
4. Identify the cells that were the largest.
5. Compare the cells you viewed through the microscope with the images of the cells in Figure 1.
6. Describe some of the difficulties of drawing cells seen through a microscope.

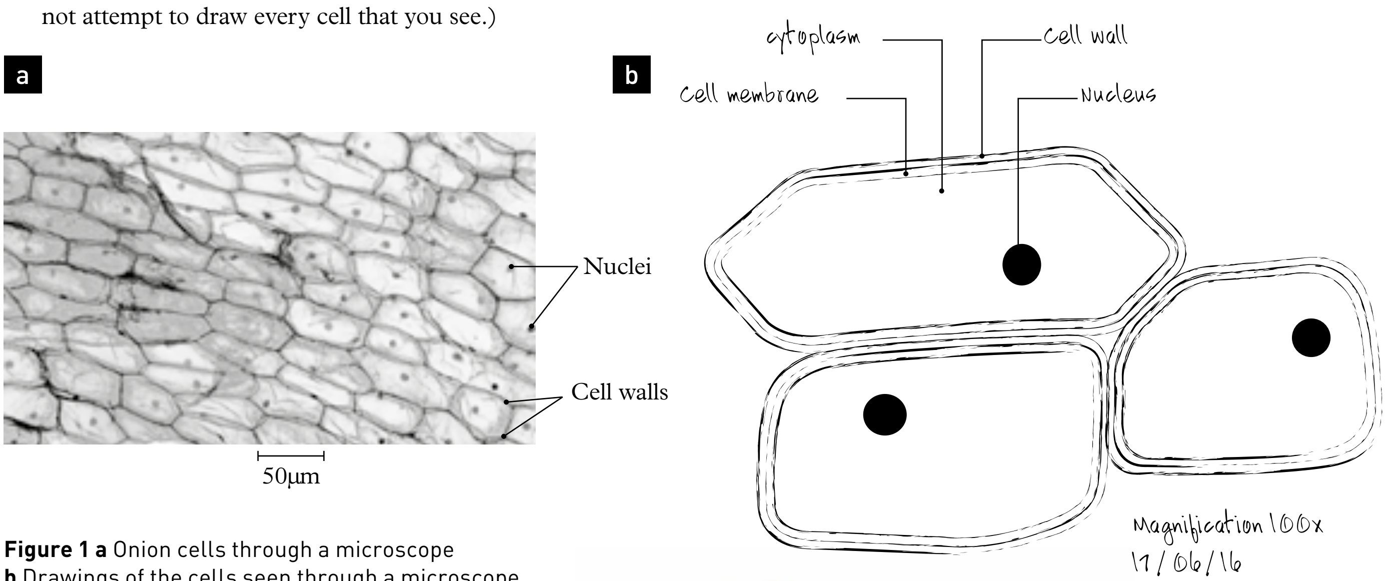


Figure 1 a Onion cells through a microscope
b Drawings of the cells seen through a microscope

Figure 2 Keeping cells under wrap

6.2 Getting to know your microscope

SKILLS LAB

What you need

- Compound light microscope
- Microscope slide
- Coverslip
- Small piece of newspaper
- Eyedropper
- Small beaker of water
- Small piece of tissue paper
- Hair (use your own)
- 1 cm sticky tape (transparent)

Figure 1 Use scissors to cut out words from the newspaper.

Figure 2 Gently lower the glass coverslip down until it is flat.

What to do

1 Always use two hands to carry a microscope – one hand should be around the main part of the instrument and the other underneath it.

2 Some microscopes have a built-in lamp. Others have separate lamps that need to be set up so they shine onto the mirror. Adjust the mirror to project the light through the stage onto the specimen. Do not allow sunlight to shine directly up the column.

3 Place the slide on the stage, then select the objective lens with the lowest magnification first.

4 Cut out two small words from a piece of newspaper.

5 Place the cut-out newspaper on the microscope slide and add two drops of water to help it 'stick' to the slide. Place a coverslip on top. This is called a wet mount.

6 Look from the side and adjust the coarse focus knob so that the objective lens is *just above – and not touching* – the slide. Check which way you must turn the knob to move the objective lens away from the slide.

7 Use the coarse focus knob to bring the specimen into view. Find one letter from the newsprint to focus on.

8 Move the slide slightly towards your body and observe what happens.

9 Move the slide slightly to the left and observe what happens.

10 Increase the magnification by rotating the objective lens to a higher magnification.

11 Draw a diagram of the newspaper letter (as a record) using a sharp lead pencil. Never colour or shade areas; if absolutely necessary, use dots or lines instead.

12 Calculate the total magnification.

13 Write the magnification next to your sketch.

14 Label and date the sketch.

15 Remove the newspaper from the microscope stage and prepare another slide using the tissue paper. Make sure a drop of water is added and the coverslip is placed over the top carefully.

16 Sketch what you see.

17 Repeat with a piece of sticky tape and then a hair from your head.

Figure 3 Carefully adjust the focus of the microscope.

Figure 4 Repeat with a piece of sticky tape.

Questions

1 Describe the direction (right way up or upside down) of the letters on the newspaper with and without the microscope.

2 Describe the features you could see on the tissue paper and sticky tape that you could not see with the naked eye.

3 Use a series of cause-and-effect graphic organisers, similar to that shown in Table 1, to record the results of your experiment when you moved the slide in different ways. For example, the cause link may be 'move the slide to the left'. Then write what happened in the effect link.

Table 1 Cause-and-effect graphic organiser

Cause	→	Effect
What did you do to cause the change you observed?		What effect did it have?

6.3A Comparing the size of cells and their parts

CHALLENGE

What you need

- Sheet of poster paper
- Pencil
- 30 cm ruler
- Eraser

What to do

Part A

Use a scale of 1 cm : 1 μm to draw a series of circles to represent the average size of various cells and microbes according to the measurements given in Table 1.

Table 1 Average diameters of different cell types

Cell type	Average diameter (μm)
Human cheek cell	30
Human red blood cell	7
Human white blood cell	25
Epidermal plant cell	50
Staphylococcus bacterium (spherical)	1
Escherichia coli bacterium (rod shaped)	3

Part B

Organelles vary in size. Some organelles, such as chloroplasts, are large enough to be visible under the light microscope. Others, such as mitochondria, are usually too small to be visible.

Use the measurements given in Table 2 to add a chloroplast and a mitochondrion (singular) to your set of diagrams.

Table 2 Size of cell organelles

Cell organelle	Average size (μm)
Chloroplast	5 μm long × 1.5 μm wide
Mitochondrion	2 μm long × 1 μm wide

Questions

1 Rank the cells and microbes in part A from smallest to largest.

2 Identify which of the cell organelles in Table 2 are not visible under the light microscope.

3 Viruses are much smaller than bacterial cells. For example, the influenza virus, which causes the flu, is 0.1 μm in diameter. Add the influenza virus to your diagrams.

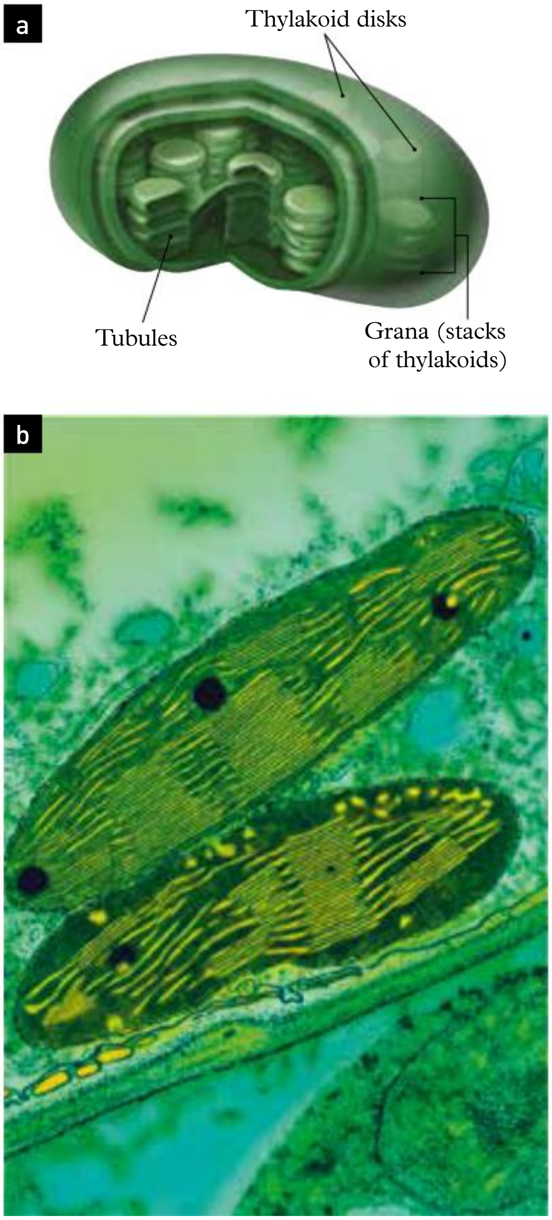


Figure 1 a Schematic diagram showing the structure of a chloroplast **b** Electron micrograph of chloroplasts

6.3B Looking at organelles

EXPERIMENT

Aim

To prepare slides to view the organelles in the cells of a brown onion and an *Elodea canadensis* plant. You may wish to review Skills lab 6.2 for slide and microscope use.

Materials

- Onion wedge
- 3 glass slides
- 3 glass coverslips
- Water
- Light microscope
- Methylene blue stain or iodine
- Leaf from an *Elodea canadensis* plant
- Blotting paper
- Dropper

Method

Onion skin cells – unstained

Light microscopes depend on the light being able to pass through the specimen. When preparing a slide, it is important that the specimen is as thin as possible.

1 Between the fleshy layers of an onion there are some thin, transparent layers. These layers are one cell thick. Peel off a layer of this skin and put it onto a microscope slide.

2 Add one drop of water and then gently lower the coverslip so that no air bubbles are trapped.

3 Draw and label what you see. Try to identify the nucleus, which contains the DNA, and the cell membrane and cytoplasm.

4 Keep this slide for use in the next part of the experiment.

Onion skin cells – stained

Stains are often used on specimens because they add contrast to the image. Some highlight a particular feature of the cell.

5 Use another thin layer of onion skin to prepare a second slide as above.

6 Add a drop of methylene blue stain or iodine instead of the water before lowering the coverslip. Lower it carefully so that no air bubbles are trapped. Be careful not to get the stain on your skin or clothes because it is very hard to remove.

7 Draw and label what you see.

Elodea canadensis cells

8 Pick a small green *Elodea canadensis* leaf and put it onto a microscope slide.

9 Add one drop of water and then gently lower the coverslip so that no air bubbles are trapped.

10 Draw and label what you see. Try to identify the cell membrane and cytoplasm.

Figure 1 Add a drop of water to the slide, then add a coverslip.

Results

Include your labelled diagrams in this section.

Discussion

1 Describe how the use of a stain changes the image of the onion cells.

2 Both types of cells viewed are from plants. Explain why there are differences between each of the cell types. (HINT: Consider which part of the plant the cells come from.)

3 Explain why it is often difficult to identify the nucleus in the *Elodea canadensis* cells.

4 The *Elodea canadensis* cells contain another structure that is very prominent. Identify and describe the function of this structure.

5 Explain why it is not necessary to stain the *Elodea canadensis* cells.

Conclusion

Explain what you know about the organelles in onion cells and *Elodea canadensis* cells.

6.3C Measuring cells

EXPERIMENT

Aim

To measure the size of various plant and animal cells using a mini-grid.

Materials

- Onion cell slide (prepared in Experiment 6.3A)
- Light microscope
- Mini-grid slide or 1 mm graph paper photocopied onto a transparency
- Other various prepared slides, such as human blood, nerve cells, leaf epidermis

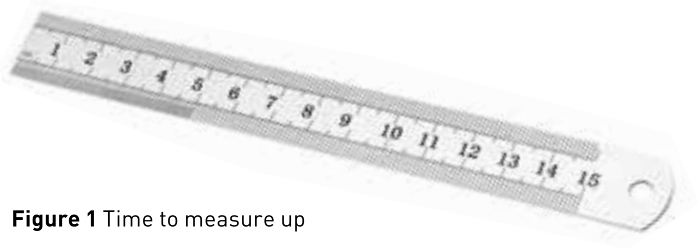


Figure 1 Time to measure up

Method

1 Focus the onion cells under the light microscope.

2 Once in focus, estimate the number of cells that can fit lengthways across the field of view (the circle of light seen down the microscope). Record your estimation.

3 Gently remove the slide and insert the slide containing the mini-grid. Adjust the focus so that the lines can be clearly seen.

4 Each box is 1 mm in length. Determine the length of the field of view by counting how many 1 mm boxes fit across the light field.

5 Use this measurement to calculate the average length of one onion cell by estimating how many cells fit across the light field.

$$\text{Length of cell} = \frac{\text{Number of cells that can fit lengthways}}{\text{Field of view length (mm)}}$$

6 Repeat this process for each of the other prepared slides.

Results

Rank the cells viewed in size from smallest to largest.

Discussion

1 Identify the number of micrometres in 1 mm.

2 Compare the ranking of cell size in this experiment to Table 2 from Challenge 6.3A.

Conclusion

Describe what you know about the relative sizes of plant and animal cells.

6.4A Classifying using cells

CHALLENGE

What you need

- Light microscope
- Four pre-prepared cells labelled A–D, supplied by your teacher (these may include leaf epidermal cells, yeast cells, protea cells or animal cells)

What to do

1 Look at each slide under the microscope.

2 Using Table 1 to help you, classify each slide into one of the five kingdoms.

3 Use a table like the one below to present your results.

Table 1 Cells and their key features

Slide	Average diameter (μm)	Kingdom	Evidence to support your selection
A	30		
B	7		
C	25		
D	50		

Questions

1 Name the key features that can be used to identify a cell in Kingdom Animalia.

2 Identify the key features that can be used to identify a cell in Kingdom Plantae.

3 Identify the key features that can be used to identify a cell in Kingdom Fungi.

6.4B Plant and animal cells

EXPERIMENT

Aim

To compare plant and animal cells.

Materials

- Brown onion
- Microscope slide
- Coverslip
- Iodine in dropper bottle
- Light microscope
- Prepared slide of animal cells

Method

1 Peel off a very thin piece of brown onion skin so that it looks a bit like cling film.

Figure 1 Peeling an onion

2 Place the skin on the microscope slide and add a tiny drop of iodine. This stains parts of the cells to make them easier to see.

Figure 2 Adding iodine to onion skin

3 Place one edge of the cover slip onto the slide and carefully lower it so that no air bubbles are trapped underneath.

Figure 3 Placing the cover slip on the slide

4 Place the slide on the stage.

5 Focus the microscope.

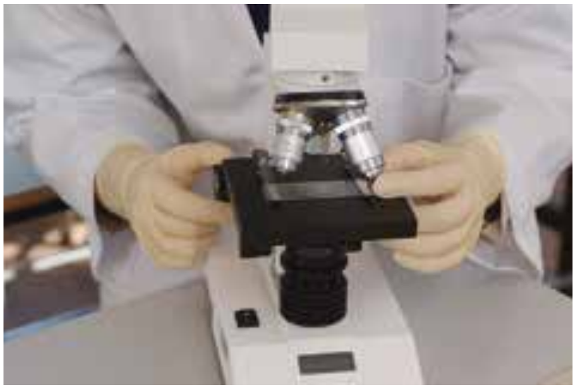


Figure 4 Focusing the microscope

6 Draw three onion cells that you observed. Don't forget to label your diagram and write down the total magnification.

7 Remove the slide and place the prepared slide of animal cells under the microscope. Focus the microscope.

8 Draw three cells that you observed.

9 Write down the total magnification and label the diagram.

Results

Include your cell diagrams here.

Discussion

1 Explain the purpose of staining the onion skin cells.

2 Compare the two sketches you have prepared with the images of plant and animal cells in Figure 1 on page 120. Identify the differences and similarities between the cells.

3 Use the Venn diagram in Figure 5 to show how plant and animal cells are similar and how they are different.

Conclusion

Describe what you know about plant and animal cells.

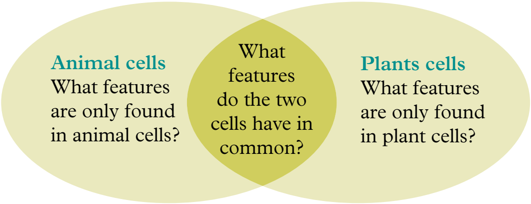


Figure 5 A Venn diagram can be used to show the similarities and differences between plant and animal cells.

6.5 Microbes all around

EXPERIMENT

CAUTION! Do not open the agar plate after incubation.

Background

In this activity you will investigate whether common detergents can kill the bacteria found in the local environment. Most human pathogenic bacteria and fungi (those that are potentially harmful to humans) grow optimally at 37°C. For this reason, samples should be sealed with paraffin wax or tape prior to incubation and destroyed immediately after analysis.

Aim

To determine the effectiveness of detergents in killing or restricting bacterial growth.

Materials

- 3 Petri dishes containing nutrient agar (called an 'agar plate')
- 2 sterilised swabs
- Paraffin wax strips
- Incubator set at 37°C
- Marker pen
- Plastic bag for dirty swabs

Figure 1 Carefully wipe the swab over the agar plate.

Method

1. Two of the agar plates are to be used for growing microbes and the third is the negative control plate. The negative control plate should not be opened at any stage of the activity, but must be incubated alongside the sample plates.
2. Decide on a site around the school to be tested for microbes.
3. Keep the swabs sterile (germ free) until you reach the site.
4. Rub the swab over the site and then gently rub it across the surface of the agar in both directions. Take care not to damage the surface of the agar.
5. Quickly place the lid on the plate, seal it with a wax strip and then incubate it, along with the control plate, at 37°C for 2–3 days. Do not open the agar plate again.

Inquiry: What if a detergent was spread over the surface of the agar plate?

- Choose a detergent that you would like to test.
- Write a prediction or hypothesis for your experiment.
- What (independent) variable will you change from the first method?
- Describe how you will know if the detergent is effective in killing/restricting bacterial growth. (This is your dependent variable.)
- Identify two variables that you will need to control to ensure a fair test. Describe how you will control these variables.
- Write in your logbook the method you will use to complete your investigation.
- Draw a table to record your results.
- Show your teacher your planning (for approval) before starting your experiment.

Discussion

1. Describe the growth on your sample plates after the incubation period. A labelled diagram may help you to do this. Identify the growth of bacteria and fungi that may be growing on your sample plates.
2. If your sample plate showed evidence of bacterial growth, describe any differences in colour, shape and size of the bacterial colonies.
3. Identify whether your detergent was effective in controlling bacterial growth. Justify your answer by describing the differences in bacterial or fungal growth that occurred between the plates.
4. Describe why there may be some differences between the growth on your plates and those of other students.
5. Explain why it is important that both the swab and the plate are sterile and are only exposed to the environment for a short period while collecting the sample.
6. If the negative control plate was sterilised appropriately prior to the beginning of this activity and then incubated alongside the sample plate, it should have shown no bacterial or fungal growth. Explain the purpose of the negative control plate.

Conclusion

Describe the conclusions that you can make about the effectiveness of your detergent.

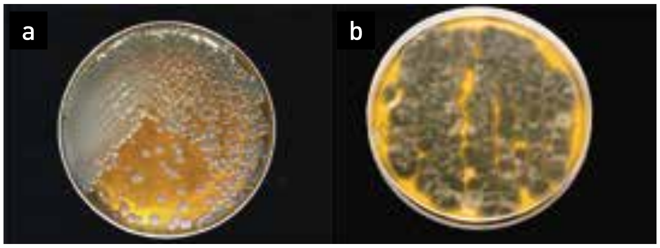


Figure 2 a Bacterial colonies growing on an agar plate
b Fungi tend to have a dusty or fuzzy appearance.

7.1 Brown paper body brainstorm

CHALLENGE

What you need

> Large pieces of butcher's paper
> Several different-coloured felt-tipped pens

What to do

1 Working with a partner, spend 5 minutes brainstorming all the internal parts of the body you can think of. Write them down in your notebook as you brainstorm.
2 Unravel 2 m of butcher's paper along the floor.
3 Have one student lie down on the paper. Trace around them.
4 Spend a minute discussing the best way to illustrate the body shape with all the body parts from your brainstorming list.
5 Then, using the list you brainstormed and any other body parts you think of as you work, make a drawing of the inside of a human body.
6 Try to make connections between body parts where you can. For example, you may want to connect the stomach to the intestines. Use different-coloured pens to illustrate the body parts that may be working together.

Questions

1 Identify two parts of the body that work together. Describe their function.
2 Compare your drawing to Figure 3 on page 131. Identify any parts of the body that may be located incorrectly. Correct your errors on the paper.
3 Identify a part of the body that you did not include in your diagram. Describe the function of this part of the body.

Figure 1 Draw a model of the survival systems of your body.

7.2A Digesting protein

EXPERIMENT

Aim

To investigate the function of pepsin, an enzyme found in the stomach, and to establish the conditions under which pepsin functions best. Egg white is being used as the source of protein in this experiment.

Materials

- 4 test tubes and a test tube rack
- Permanent marker
- Hard-boiled egg white
- 10 mL measuring cylinder
- 1% pepsin solution
- Water
- Dilute hydrochloric acid (1 M HCl)
- Dilute sodium hydroxide solution (0.1 M NaOH)
- 1 mL pipette
- Incubator (37°C)

Safety

Bring the materials to the test tubes, rather than risking them being dropped when carrying them around the room.

CAUTION! Some students may have egg allergies.

CAUTION! Dangerous chemicals are involved. Pour carefully, clean up all spills immediately and rinse your hands if you come into contact with any chemicals.

Method

1. Label 4 test tubes A, B, C and D with the permanent marker.
2. Collect some hard-boiled egg white. Cut four cubes of approximately 1 cm^3 ensuring that the cubes are the same.
3. Put a cube of egg white in each tube.
4. Add 10 mL pepsin to tubes A, C and D.
5. Add 10 drops of water to tube B.
6. Add 10 drops of HCl to tubes A and B.
7. Add 10 drops of 0.1 M NaOH to tube D.
8. Add 10 drops of water to tube C.
9. Bind the 4 tubes with a rubber band and label the bunch with your initials.
10. Incubate for at least 24 hours at 37°C.

Results

Record the ingredients for each tube with a tick or cross in Table 1. Provide very brief statements to describe your observations of the results.

Table 1 Investigating pepsin

Tube	Egg white	Pepsin solution	HCl	NaOH	Water	Results
A						
B						
C						
D						

Discussion

1. This experiment is a ‘controlled’ experiment. Describe what is meant by the term ‘controlled’.
2. Explain why combining the class’s data can improve the accuracy of the results.
3. Construct a sentence to explain how the comparison of tubes relates to the human stomach for A and B, A and C, and A and D.
4. Identify the test tube(s) that has the protein almost completely digested. Describe the appearance of the digested protein.
5. Define the term ‘enzyme’.
6. Describe the effect HCl alone has on the protein.
7. Copy and complete the following word equations to show what has happened in this experiment.

   Tube A: protein + __________+__________ → amino acids

   Tube B: water +__________ +__________ → __________

   Tube C: pepsin + __________+ __________ → __________

   Tube D: pepsin +__________ +__________ → __________
8. Explain why the body digests protein by describing what happens to the protein after it has been digested.
9. Predict what would happen if this experiment was repeated with carbohydrates instead of protein, leaving the rest of the experiment exactly the same.

Conclusion

Explain what you know about the function of pepsin and the conditions under which pepsin functions best.

7.2B What if an enzyme was boiled?

EXPERIMENT

Background

The gelatine in jelly is a protein that can be broken up by an enzyme found in fresh pineapple or kiwi fruit. For this reason many packets of jelly come with a warning not to add fresh fruit to the jelly.

Aim

To determine what conditions are needed for an enzyme to digest protein.

Materials

- Jelly crystals
- Boiling water to make up jelly
- Large beaker to make up jelly
- 3 × 100 mL beakers
- Fresh pineapple
- Boiled pineapple
- Tinned pineapple

Method

1. Make up the jelly according to the instructions on the packet.
2. Pour 50 mL of liquid jelly into two beakers.
3. Add a few pieces of the fresh pineapple to one of the beakers.
4. Allow to cool overnight in the fridge.
5. Record your observations in a table.

Inquiry: Choose one of the questions below to investigate.

- What if the pineapple was boiled before being added to the jelly?
- What if tinned pineapple was added to the jelly?

Answer the following questions in relation to your inquiry.

- Write a prediction or hypothesis for your inquiry.
- Identify the (independent) variable that you will change from the first method.
- Identify the (dependent) variable that you will measure and/or observe.
- Identify two variables that you will need to control to ensure a fair test. Describe how you will control these variables.
- Write in your logbook the method you will use to complete your investigation.
- Draw a table to record your results.
- Show your teacher your planning (for approval) before starting your experiment.

Results

Draw a table to record your observations.

Discussion

1. Describe the difference between the jelly with the fresh pineapple and the jelly with no pineapple.
2. Use the term ‘chemical digestion’ to explain your observations.
3. Compare your hypothesis to the results obtained in your inquiry.
4. Suggest an alternative reason for the results you obtained in your inquiry.

Conclusion

Explain why you should not add fresh pineapple to jelly.

Figure 1 Fresh pineapple

7.5A

Measure your lung capacity

CHALLENGE

CAUTION! Tubing or bendy straws must be discarded after a single-person use.

What you need

- A large 5 L container with single litres marked
- Access to a large sink or tub
- 1 m of tubing or bendy straw

What to do

1 Place 10 cm of water in the bottom of a sink.
2 Fill the container with water.
3 Tip the container upside down in the sink so that the opening is submerged. This will prevent the water from leaving the container.
4 Place one end of the tubing under the opening of the container.
5 Take a deep breath and blow as much as you can into the tubing. As you blow air into the container, the water should be pushed out the bottom.
6 Measure how much air you are able to blow out of your lungs into the container.
7 Repeat the measurement two more times.

Questions

1 Explain why the experiment needed to be repeated three times.
2 Identify two factors that could reduce a person's lung capacity.
3 Compare your results with those of other students in the class. Identify any relationship between height of the person and their lung capacity.

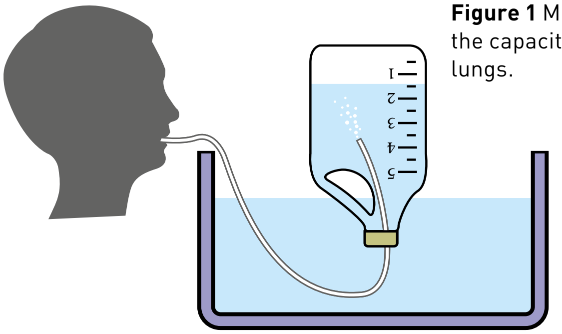


Figure 1 Measure the capacity of your lungs.

7.5B

Fish dissection

CHALLENGE

What you need

- A fish, complete with internal organs, from a fishmonger or market
- Dissection tools
- Newspaper
- Dissection board

CAUTION! Refer to Chapter 1 for dissection skills and safety guidelines.

PART A

What to do

Use your dissection skills to open the abdomen and head of the fish and record your observations of the internal organs, using labelled diagrams.

Questions

1 Identify whether the systems are clearly separated or intertwined.
2 Compare the colour (dark red, light red or white) of the different organs.
3 Explain how an organ's blood supply could affect their colour.
4 Explain how the amount of blood supply is related to an organ's importance.

PART B

What to do

Identify and remove the gills of the fish. Reflect on the significant features of our lungs that make them such effective gas exchange organs.

Questions

1 Compare the structure of fish gills to lungs in a mammal (i.e. human).
2 Compare the function of fish gills and mammalian lungs.
3 Explain how the structure of fish gills allows them to function effectively.

Figure 1 Identify the key organs in the dissected fish.

7.7 Heart dissection

EXPERIMENT

CAUTION! Refer to Chapter 1 for dissection skills and safety guidelines.

Aim

To explore the structure and function of a heart.

Materials

- Sheep, cow, ox or pig heart
- Scalpel
- Newspaper
- Dissecting probe and forceps

Method

1 Examine the outside of the heart and identify the left and right sides. Your fingers will work better than a probe for that.

2 Use your fingers to feel the right side of the heart. Compare the thickness of the right and left sides. Feel the muscle in the centre of the heart.

3 Using a scalpel, cut open the right atrium and right ventricle. Pull back the wall and look inside to see the atrium and the ventricle. The ventricle is the chamber closest to the pointed end of the heart. The white tendons hold the valves in place.

4 Push a dissecting probe or your finger out through the artery leading from the right ventricle.

5 Cut open the left side of the heart. Locate the atrium, ventricle and tendons holding the valves.

6 Push a dissecting probe or your finger out through the artery leading from the left ventricle.

Results

Include labelled diagrams and observations here.

Discussion

1 Identify the name of the artery from step 4.

2 Identify the name of the artery from step 6.

3 Compare the thickness of the artery wall with the thickness of a vein wall.

4 Compare the thickness of ventricle walls with that of arterial walls.

5 Explain the difference between the left and right ventricle walls.

Conclusion

Explain what you know about the structure and function of the heart.

Figure 1 Identify the right and left sides of the heart.

Figure 2 Compare the thicknesses of the right and left ventricles.

Figure 3 Use the dissecting probe to identify the arteries.

Figure 4 Identify the artery leaving the left ventricle.

7.8

Modelling blood flow

CHALLENGE

Design brief

To model the flow of blood.

What you need

- Scissors
- Plastic cups
- 1 thin straw
- Play dough
- 1 thick straw
- Food colouring
- Water
- Large tray
- Timer

What to do

1. Use the scissors to carefully poke a straw-sized hole through the side of the plastic cup, close to the cup base.
2. Place the thin straw through the hole in the cup making sure the straw is not being squeezed.
3. Use play dough to seal around the hole so that there are no leaks. Water should only be able to escape through the straw.
4. Cut the straw so that it is 5 cm in length.
5. Repeat this with another cup for the thick straw, making sure the straw is placed at approximately the same height from the cup's base.
6. Place the cups at the tray and fill both cups with equal amounts of coloured water.
7. Time how long each cup takes to become empty.

Questions

1. Describe the effect narrowing the straw had on the amount and evenness of water flow out of the straw.
2. Identify the complication of the circulatory system that is shown in this model.
3. Treatment for this complication involves inserting a small balloon into the blood vessel and allowing it to stretch the vessel so that it becomes wider. Explain how this will help the patient.

7.9

Kidney dissection

EXPERIMENT

CAUTION! Refer to Chapter 1 for dissection skills and safety guidelines.

Aim

To investigate the structure of a mammalian kidney and explore the various functions of the different parts.

Materials

- Sheep's kidney
- Dissecting kit
- Dissecting board

Method

1. Place the whole kidney on the board and identify as many parts as possible.
2. Draw a labelled diagram.
3. Cut the kidney in half longitudinally (lengthways).
4. Draw a labelled diagram. Identify any key structures that you can see.

Results

Include your labelled diagrams here.

Discussion

1. Compare the colour of the kidney on the outside with the colour on the inside.
2. The colour of the kidney gives an indication of the amount of waste products it contains. Use your answer to question 1 to identify whether the outside or inside of the kidney produces the most waste.
3. Explain why you cannot see any nephrons with your naked eye.
4. The medulla, the middle section of the kidney, has a stripy appearance. This is due to the collecting ducts heading in the same direction. Identify the function of the collecting ducts.

Conclusion

Describe what you know about the form and function of a mammalian kidney.

7.10A Locating the stomata of a leaf

CHALLENGE

What you need

- Clear fingernail polish
- Fresh plant leaf
- Clear sticky tape
- Glass slide
- Microscope

What to do

1. Paint a thick patch of clear nail polish on the underside of the leaf and allow to dry.
2. Place a piece of the clear sticky tape over the dried nail polish.
3. Gently peel the sticky tape off the leaf, removing the nail polish patch from the leaf's surface.
4. Tape the peeled section of leaf onto the glass slide.
5. Examine the slide under the microscope and locate a stoma (singular of stomata).
6. Draw a labelled diagram of the stoma.

Questions

1. Describe the function of stomata in a plant.
2. Identify the stoma you located as either open or closed. Describe how you made this conclusion.
3. Refer to the time of day and the location of the plant to explain why the stoma on your plant was open or closed.

Figure 1 Fresh leaves

7.10B Locating the xylem and phloem in a stem

CHALLENGE

What you need

- 500 mL beaker
- Water
- Blue or red food colouring
- Fresh stick of celery
- Scalpel and cutting board
- Permanent marker
- Magnifying glass

What to do

1. Add 200 mL of water to the beaker.
2. Add 15 drops of food colouring to the water.
3. Cut the bottom 10 cm off the celery.
4. Place the top half of the celery in the beaker of coloured water.
5. Mark the water level with a permanent marker. Leave for 2–3 days.
6. Remove the celery from the water and use the scalpel to cut a horizontal transverse section of the celery stalk.
7. Locate the pathway by which the coloured water moved through the celery. Draw a labelled diagram of the celery cross-section.

Questions

1. Describe how the amount of water in the beaker changed after 2–3 days.
2. Use the term 'transpiration' to explain your answer to the previous question.
3. Identify the name of the pathway that moved the coloured water through the celery.
4. Compare the circulatory system you observed with the circulatory system in humans.

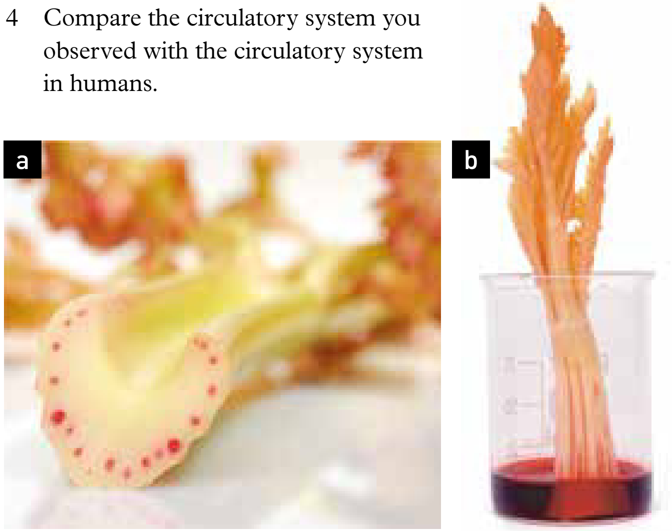


Figure 1 a The dye marks the path the water takes from the roots. **b** As water evaporates from the leaves, the coloured water replaces it.

7.10C Modelling root cells

CHALLENGE

Design brief

To model root cells of a plant.

What you need

- 15 cm dialysis tubing
- Water
- 5 mL of 2% starch solution
- Scales
- 200 mL beaker
- 10 mL measuring cylinder

What to do

1. Soften the dialysis tubing by running water over the outside of it.
2. Tie a knot in one end of the tubing.
3. Add 5 mL of starch solution to the tubing.
4. Seal the open end by tying a knot.
5. Wash the outside of the tubing with water.
6. Pat dry the outside of the tubing and use scales to determine its weight.
7. Place the tubing in the beaker. Add 100 mL water.
8. Leave overnight.
9. Remove the dialysis tubing from the water and carefully pat dry.
10. Determine the weight of the dialysis tubing.

Questions

1. Contrast the weight of the dialysis tube with starch before and after soaking in water.
2. Explain the change in the weight of the tubing.
3. Define the term ‘osmosis’.
4. Use the term ‘osmosis’ to explain how the dialysis tubing is similar to the cells in a root.

7.10D Factors that affect transpiration

EXPERIMENT

Aim

To determine the factors that affect the transpiration of water from plants.

Materials

- 250 mL measuring cylinders
- Water
- Fresh celery stalks

Method

1. Add 100 mL of water to one of the measuring cylinders.
2. Discard the bottom 10 cm of a celery stalk and trim so that the end of it fits into the measuring cylinder.
3. Place the top half of the celery in the measuring cylinder.
4. Mark the water level with a permanent marker. Leave for 2–3 days at room temperature.
5. Measure how much water has been lost by the celery stick.

Inquiry: Choose one of the questions below to investigate

- What if the celery was placed in sunshine?
- What if the celery was placed in wind? (A fan may be used.)
- What if the celery was placed in a humid environment? (A large clear plastic bag may be placed over the celery.)

Answer the following questions in relation to your inquiry.

- Write a prediction or hypothesis for your inquiry.
- Identify the (independent) variable that you will change from the first method.
- Identify the (dependent) variable that you will measure and/or observe.
- Identify two variables that you will need to control to ensure a fair test. Describe how you will control these variables.
- Write in your logbook the method you will use to complete your investigation.
- Draw a table to record your results.
- Show your teacher your planning (for approval) before starting your experiment.

Results

Record your observations and measurements in a table.

Discussion

1. Define the term ‘transpiration’.
2. Identify two factors that you expect to affect transpiration.
3. Compare your results to your hypothesis. Use evidence from your results to support your answer.
4. Describe how you could use your results to support the plants in your garden.

Conclusion

Explain what you know about the factors that affect transpiration.

8.1 Vegetative propagation

EXPERIMENT

Aim

To produce a new plant using vegetative propagation.

Materials

- 2 x 500 mL beakers
- Water
- Scissors
- Geranium plant
- Flowerpots with potting mix

Method

1 Fill the beakers 3/4 full with water.
2 Use the scissors to cut four healthy stems with 1–2 healthy leaves on each from the same plant.
3 Place the cut ends of the stems into the water.
4 Observe the cut ends of the stems for 2–3 weeks.
5 Transfer the cuttings to the flowerpots.
6 Water the plants regularly and observe their growth.

Results

Record your observations in a logbook. Take photos of any changes in growth.

Discussion

1 Identify this form of reproduction as sexual or asexual. Use evidence from your experiment to justify your answer.
2 Compare the genetic material in the parent plant with that of the new (daughter) plants.
3 Identify whether the parent and daughter plant will be identical in shape and size. Justify your answer by describing the factors that affect plant growth and comparing them to the decision you made.
4 A student claimed that they were making plant clones. Define the term 'clones'. Use your definition to evaluate if the student's claim is correct.

Conclusion

Describe what you know about vegetative propagation.

8.4 Working with the RSPCA

CHALLENGE

Background

The RSPCA is a community-based charity, well known in Australia for its work with and for animals. Unlike humans, animals do not have a voice and so they cannot ask for help. The RSPCA is one of the best 'voices' for animals and their rights. One of the RSPCA's biggest campaigns is about desexing, mostly to do with cats. Every year, approximately 60 000 cats are brought in to the RSPCA; of these, over half have to be put down.

Aim

To create a mathematical model (or diagram) demonstrating how many cats can be produced from two fertile cats.

What to do

The growth modelled in this task is exponential, meaning that when the two cats reach 6 months of age they can start to breed and, after 60 days, will have a litter of four kittens, after 6 months these four kittens will also be able to have kittens themselves and so on. Cats can start the breeding cycle almost straight after having kittens, which means, on average, cats can have three litters of kittens a year.

Include a graph that shows the growth of numbers of cats against time.

Questions

1 Explain what desexing is and why it is important.
2 Based on your calculations, identify how many cats were produced after 4 years.
3 Describe how desexing the first mating pair would change your calculations.
4 Identify two other factors that could affect the number of cats in your calculations.
5 Explain why the RSPCA takes in so many more cats than dogs.

Figure 1 Counting kittens

8.5 Flower dissection

EXPERIMENT

Aim

To identify and draw a labelled diagram of a plant's reproductive organs.

Materials

- Newspaper
- A flower (you can dissect any type of flower available; lilies and fuchsias are a good choice)
- Scalpel blade or sharp knife
- Hand lens
- Dissecting scissors
- Dissecting board

Method

1. Place the newspaper on the bench.
2. Cut the flower off the stalk.
3. Observe the flower. Identify the main parts of the flower from Figure 1.
4. Draw a labelled diagram of the flower.
5. Gently remove the sepals and petals.
6. Look for the stamens with anthers at the top. The anthers hold the pollen. You should be able to dust some pollen onto your finger.
7. Cut off the male parts at the bottom of the petal.
8. Observe the female part of the flower. It has the stigma at the top and the ovary at the bottom.
9. Cut the ovary lengthwise. In it you will see tiny white scales, which are the ovules. When the ova inside the ovules are fertilised by the pollen, they will grow to become seeds and the ovary will grow to become the fruit.
10. Draw a labelled diagram of the ovary.
11. Clean up your bench by wrapping the flower in the newspaper. Wash your hands.

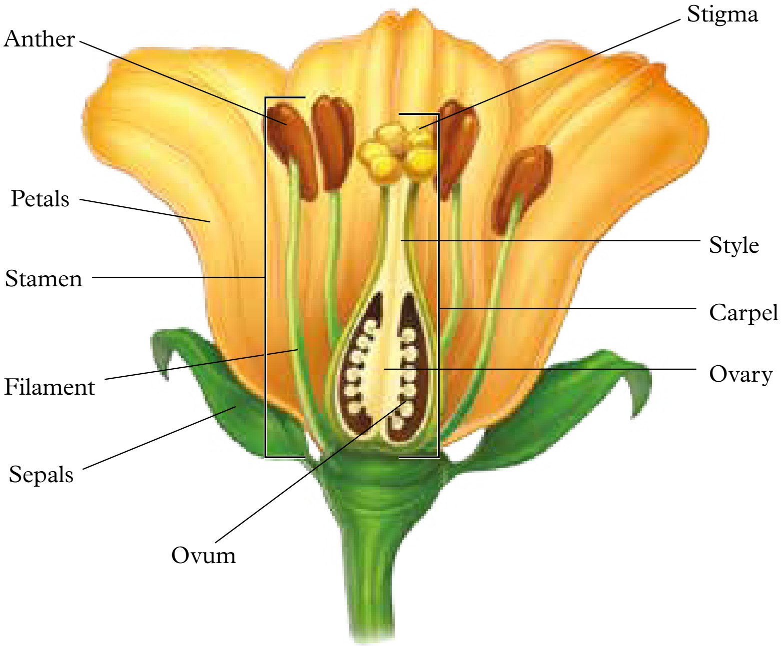


Figure 1 The structure of a flower

Results

Draw labelled diagrams of the male and female parts of the flower.

Discussion

1 Identify the colour of the filament (the stem of the stamen).
2 Describe how easy it was to clean the pollen from your fingers. Explain the advantage of a plant having sticky pollen.
3 Explain how the male and female parts were arranged to encourage pollination.
4 Identify whether your flower is more likely to be self-pollinated or cross-pollinated. Justify your answer (using your observations to explain how the plant would be pollinated).
5 Identify whether pollination is more likely to be by wind, water or animals. Justify your answer.

Conclusion

Explain what you know about the parts of a flower.

Figure 2 Calla lilies

Figure 3 Fuchsias can be used in this experiment.

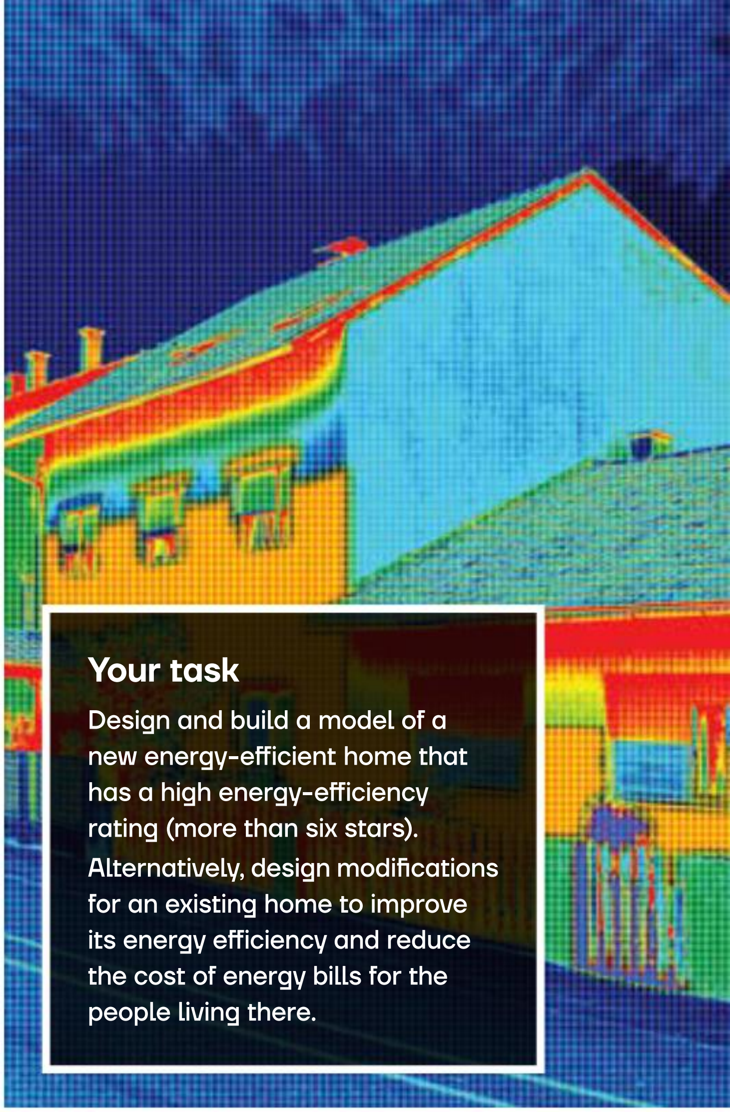
[STEAM project 1]

How can we build more energy-efficient homes so that we live more sustainably?

Have you ever considered how much energy it takes to heat or cool your home? A study by the Australian Government found that homes contribute 11 per cent of Australia's total carbon emissions. Reducing the amount of energy needed to heat or cool a home will not only save people money on their gas and electricity bills, it will make housing more sustainable.

NatHERS

The Nationwide House Energy Rating Scheme (NatHERS) is a rating system that is used across Australia to identify the energy efficiency of homes (where ten stars is the most energy efficient). Computer modelling software uses the local climate, the orientation of the home and materials used in construction to estimate the amount of energy needed to heat or cool the home. In most states and territories of Australia, new homes must reach a minimum of six stars to be approved for construction. There are many ways to improve the energy efficiency of your home. For example, if you insulate the walls, floors and roof, and use awnings (covers that extend over windows or doors), you can reduce the amount of thermal energy needed to cool the home in summer. Or in cooler climates, if you design the home so that living areas are on the northern side, you can maximise the sunlight that is available to heat the home in winter.



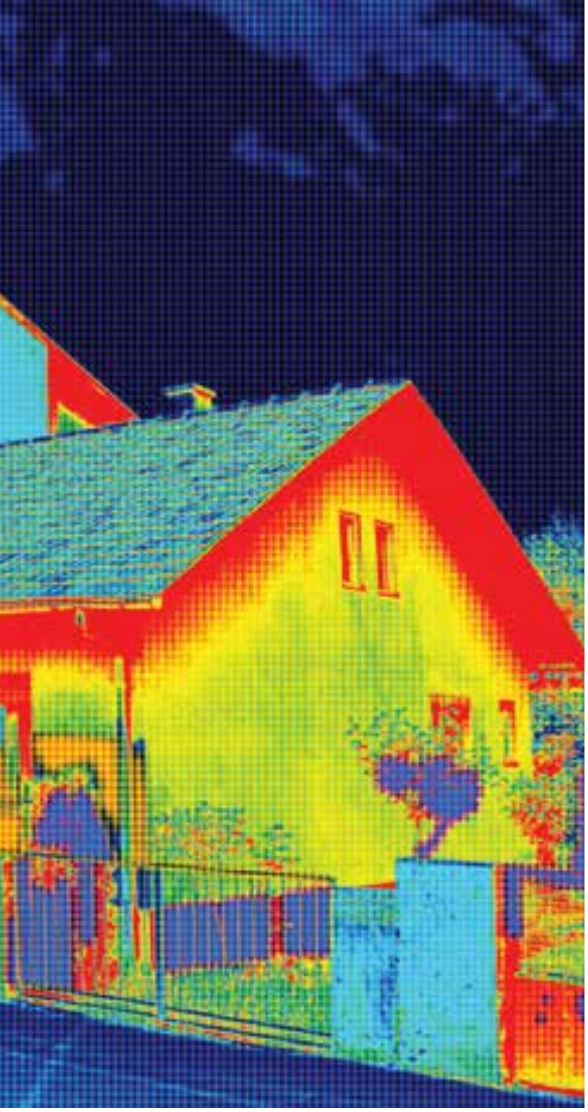
Your task

Design and build a model of a new energy-efficient home that has a high energy-efficiency rating (more than six stars). Alternatively, design modifications for an existing home to improve its energy efficiency and reduce the cost of energy bills for the people living there.

Figure 1 Infrared imaging shows warmer temperatures as red and cooler temperatures as blue. A building with insulation will lose less thermal energy to the outside environment in winter and will gain less thermal energy from the outside environment in summer.

Retrofitting homes

Not everyone wants to or can afford to build a new home. People who rent sometimes have little choice when it comes to the energy efficiency of their home, but this doesn't mean that they need to have large gas and electricity bills. There are things that they can do to reduce the movement of thermal energy in summer or winter. Covering the floor with rugs, preventing heat from moving in or out of windows, and controlling windows to manage airflow are all ways to make a home more energy-efficient and liveable.



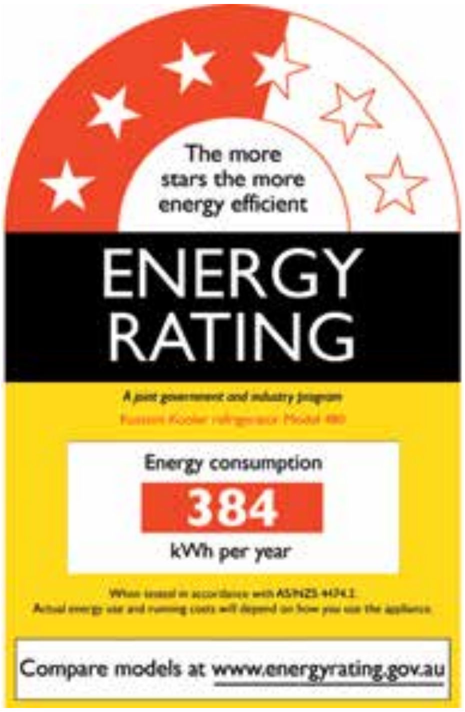


Figure 2 Energy rating schemes help consumers to understand the energy efficiency of products or appliances. The more stars, the more energy efficient the product or appliance is.

HUMANITIES

In Geography this year, you will learn about the importance of sustainable housing in Australia's urban centres and major cities. You will explore how the forecasted growth of Australia's cities could impact their liveability, and the environmental issues resulting from urbanisation.

In Economics and Business, you will study the role and social responsibilities of businesses in reducing their environmental impact, and how these businesses can be attractive to consumers who want to make sustainable choices.

To complete this task successfully, you will need to study seasonal weather patterns at the location of your energy-efficient home, to improve energy use.

You will find more information on this in Chapter 5 'Urban life' and Chapter 21 'The world of business' of *Oxford Humanities 8 Victorian Curriculum*.

MATHS

In Maths this year, you will learn how to determine the area and volume of different shapes, using and converting between appropriate units. You will also learn skills for dealing with percentage changes and profit and loss. These skills will help you to quantify the costs and benefits of design features and predict the popularity of market incentives. You will perform calculations with and without digital technology.

To complete this task successfully, you will need to perform calculations for your model home, and then scale up to estimate the potential benefits of your design at a national level.

You will find help for applying these maths skills in sections 3B 'Percentage calculations', 3C 'Financial calculations', 8D 'Area of quadrilaterals' and 8E 'Area of a circle' of *Oxford Maths 8 Victorian Curriculum*.

SCIENCE

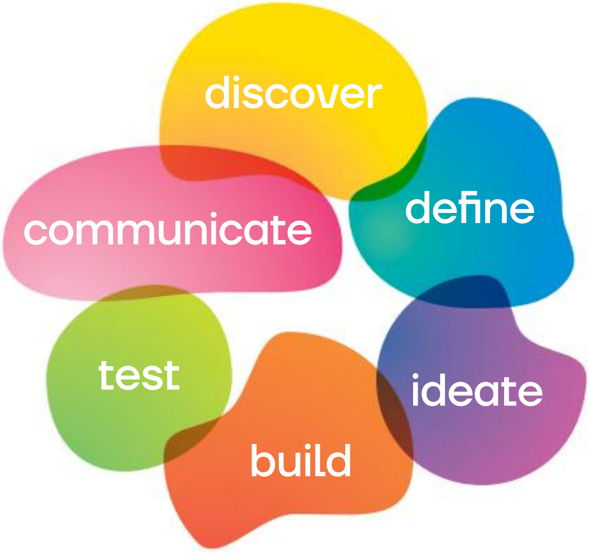
In Science this year, you will learn about how thermal energy can be transferred between objects (such as between a home and its surroundings). You will also examine the impact that insulation, window awnings and verandas have on the ability of a home to stay cool in summer.

To complete this task successfully, you will need to identify how each element of a home's design can affect its heating and cooling needs. You will also need to identify the elements that can be changed in a new home design, and compare these to the elements that can be changed in an established home.

You will find more information on this in Chapter 3 'Energy' of *Oxford Science 8 Victorian Curriculum*.

The design cycle

To successfully complete this task, you will need to complete each of the phases of the design cycle.



Discover

When designing solutions to a problem, you need to know who you are helping and what they need. The people you are helping, who will use your design, are called your end-users.

Consider the following questions to help you empathise with your end-users:

- Who am I designing for? How big is their family and home?
- What factors might affect the liveability of the home?
- What do they need? What do they not need?
- What does it feel like to face these limitations on liveability? What words would you use to describe how it would feel to face these limitations?

To answer these questions, you may need to investigate using different resources, or even conduct interviews or surveys.

Define

Before you start to design your home modifications, you need to define the parameters you are working towards.

Define your version of the problem

Rewrite the problem so that you describe the group you are helping, the problem they are experiencing and why it is important. Use the following phrase as a guide.

'How can we help (the group) to solve (the problem) so that (the reason)?'

Determine the criteria

1 Describe the orientation of the land where the home will be built or modified (include the location of sunrise and sunset, the angle of sun in the middle of summer and winter and any existing shadows).
2 Describe any existing energy-efficient features of the current home or design.
3 Describe how you will measure any improvement in energy-efficient features of the home.

Ideate

Once you know who you're designing for, and what the criteria are, it's time to get creative!

- Outline the criteria or requirements your design must fulfil (for example, improving heating or cooling of the home).
- Brainstorm at least one idea per person that fulfils the criteria.

Remember that there are no bad ideas at this stage. One silly thought could lead to a genius innovation!

Build

Draw each individual design.

Include in the individual designs:

- **a** labels for each part of the design
- **b** the materials you will use for the home's construction
- **c** a description of how the modifications will improve the energy star rating of the home
- **d** an estimation of the cost of applying the modifications.

Present your design to your group.

Build the prototype

Choose and build two or three model homes for your group design (scale: 2 cm = 1 m).

Use the following questions as a guideline for your prototype.

- What materials will you need to build your model home?
- What skills will you need to build your model home?
- How will you test the effectiveness of your model home? (What will you compare it to?)
- How will you identify each energy-efficient feature of your model home?
- How will you collect data that supports your claims about energy efficiency?

Test

Use the scientific method to design and test the energy efficiency of your model home. You will test more than one design so that you can compare them, so you will need to control your variables between tests.

What criteria will you use to determine the success of your model home?

Conduct your tests and record your results in an appropriate table.

Communicate

Present your home design as though you are trying to get your peers to invest in it.

In your presentation, you will need to:

- construct a labelled diagram of your model home in its orientation, including the location of sunrise and sunset, the angle of sun in the middle of summer and winter, and any existing shadows
- describe the key energy-efficient features of your model home
- explain how each energy-efficient feature affects the liveability of your model home
- explain the principles that support your design (the importance of energy efficiency and how the existing landscape affected the design of the home)
- estimate the cost of implementing your design
- explain and quantify the benefits on a national scale if all new homes were to include your design features.

Check your Student obook pro for the following digital resources to help you with this STEAM project:

Student guidebook
This helpful booklet will guide you step-by-step through the project.

What is the design cycle?
This video will help you to better understand each phase of the design cycle.

How to manage a project
This 'how-to' video will help you to manage your time throughout the design cycle.

How to pitch your idea
This 'how-to' video will help you with the 'Communicate' phase of your project.

Check your Teacher obook pro for these digital resources and more:

Implementation advice
Find curriculum links and advice for this project.

Assessment resources
Find information about assessment for this project.

How can we use technology so that the impact of natural disasters is reduced?

Across the world, climate patterns are changing and weather events are becoming more extreme. In 2020, 20 per cent of Australia's forests were burnt, a record-breaking 30 named hurricanes developed over the Atlantic Ocean, and an extreme monsoon season in Asia caused flooding across a quarter of Bangladesh. Australia is particularly prone to natural disasters. Bushfires, flooding, drought periods and cyclones dramatically affect people's lives, and alter natural landscapes.

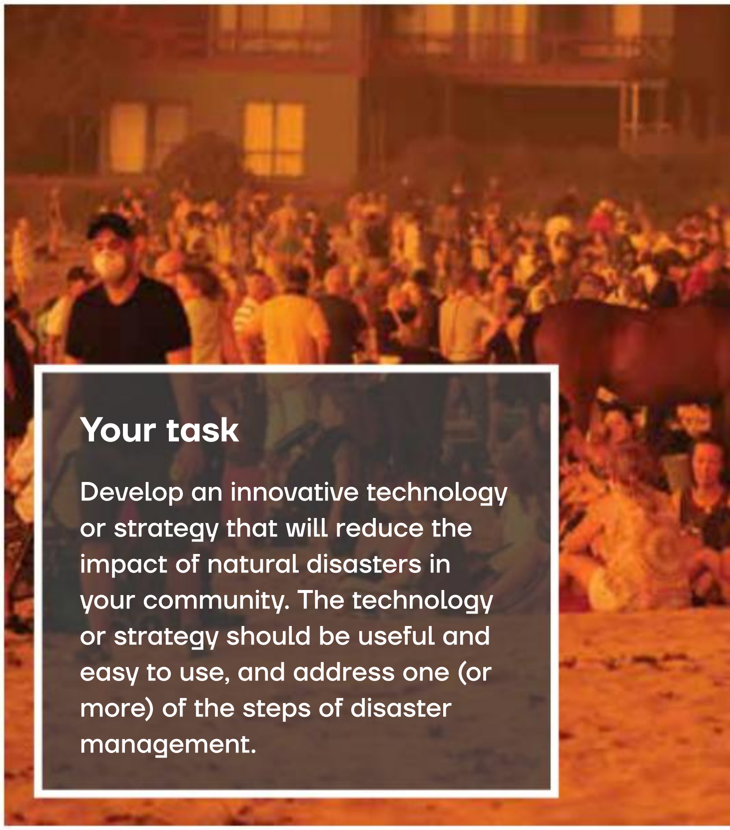
Natural disasters can be devastating for communities affected by them. Recovering from natural disasters also comes with huge economic costs. This can sometimes lead to a harmful cycle in which a nation gets stuck between experiencing disaster and responding to disaster.

Disaster management

Climate action is one of the 17 Sustainable Development Goals agreed to in 2015 by world leaders. One of the identified targets in combating climate change is to strengthen the resilience and adaptive capacity of all countries to natural disasters and hazards related to climate.

It is essential that communities prepare for disasters so as to reduce their impact. The United Nations Office for Disaster Risk Reduction (UNDRR) recommends using technology as part of disaster management, for example:

- warning systems in Japan that trigger emergency breaks in bullet trains if earthquakes are detected
- systems in sub-Saharan Africa that monitor rainfall data and analyse trends to forecast and build resilience to drought
- atlases in China that record the risk of natural disasters, using location data from spatial technologies such as GPS.



Your task

Develop an innovative technology or strategy that will reduce the impact of natural disasters in your community. The technology or strategy should be useful and easy to use, and address one (or more) of the steps of disaster management.

Figure 1 Hundreds of people (and animals) huddled on Malua Bay beach in NSW for almost 24 hours, as bushfires tore through communities in the nearby Batemans Bay area.

After the 2019–20 Australian bushfires, it was argued that satellite technology, drones and mobile phone apps would have been extremely helpful for fighting the fires and communicating with the people affected.

Disaster management should include four steps:

- prevention – reducing hazards before a disaster takes place, so its impact is not as severe (e.g. building schools that are earthquake resistant)
- preparation – training people so they know how to act when a disaster happens (e.g. running evacuation drills)
- response – taking action during a disaster (e.g. emergency crews and volunteers taking on emergency operations)
- recovery – taking action to help people rebuild their lives (e.g. restoring services in a community).

Disaster management is an ongoing process that can occur like a cycle between the phases of prevention, preparation, response and recovery.

HUMANITIES

In Geography this year, you will learn about landscapes and landforms and how they can be degraded by both human and natural causes. You will study a geomorphic hazard, its impacts on a place and various ways of responding to it.

In History, you might also study how past societies have dealt with disasters and managed their responses; for example, how Rapa Nui (Easter Island) inhabitants adapted to life without trees, how Shogunate Japan developed policies to sustain its forests, or how an unstable climate (including drought and heavy monsoons) affected the Khmer Empire.

To complete this task successfully, you will need to investigate a potential natural hazard in your local area. You will research any current disaster-response plans related to managing such an event, and gain an understanding of how various people and businesses in the community would be impacted.

You will find more information on this in Chapters 2, 16, 15 and 13 of *Oxford Humanities 8 Victorian Curriculum*.

MATHS

In Maths this year, you will consolidate and extend your skills in representing and interpreting primary and secondary data. This will include creating and analysing plots of non-linear data, investigating the use of sampling methods, and broadening your understanding of measures of spread. You will also perform calculations with percentage changes, profit and loss. You will analyse and represent data, both with and without digital technology.

To complete this task successfully, you will need to weigh up the costs of your disaster-management technology or strategy against its potential benefits, including by estimating the likelihood of natural disasters and the severity of their effects.

You will find help for applying these maths skills and statistics in sections 3B ‘Percentage calculations’, 3C ‘Financial calculations’, 6D ‘Plotting linear and non-linear relationships’, and 9A ‘Collecting data and sampling methods’ of *Oxford Maths 8 Victorian Curriculum*.

Figure 2 Floodwaters near Sydney

SCIENCE

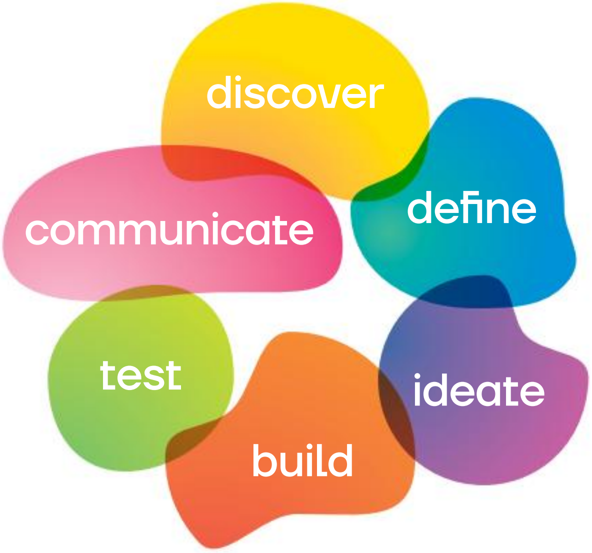
In Science this year, you will learn about how the energy of the Earth over long periods of time generates forces that can melt rocks, produce volcanoes and make diamonds. You will also learn how the kinetic energy in the air and waves can cause damage to the surrounding environments during cyclones and tsunamis. The Australian bush also contains large amounts of chemical energy that is transformed into thermal energy during the summer fire season.

To complete this task successfully, you will need to consider how energy is transferred and transformed during natural disasters. This understanding will allow you to predict and potentially reduce the impact of the disaster in your local community.

You will find more information on this in Chapter 3 ‘Energy’ of *Oxford Science 8 Victorian Curriculum*.

The design cycle

To successfully complete this task, you will need to complete each of the phases of the design cycle.



Discover

When designing solutions to a problem, you need to know who you are helping and what they need. The people you are helping, who will use your design, are called your end-users.

Consider the following questions to help you empathise with your end-users:

- Who am I designing for?
- What natural disaster could they face?
- How often could this disaster occur, and on what scale?
- What do they need? What do they not need?
- What does it feel like to face these problems? What words would you use to describe these feelings?
- What could the cost of such a disaster be in terms of lives lost, income lost, damage to private property and public infrastructure, and environmental impact?

To answer these questions, you may need to investigate using different resources, or even conduct interviews or surveys.

Define

Before you start to design your innovative strategy or technology, you need to define the parameters you are working towards.

Define your version of the problem

Rewrite the problem so that you describe the group you are helping, the problem they are experiencing and why it is important. Use the following phrase as a guide.

‘How can we help (the group) to solve (the problem) so that (the reason)?’

Determine the criteria

1 Define the term ‘innovation’. Describe how much a strategy needs to differ from current practice to be considered innovative.

2 Describe how the natural disaster will affect the people in the community.

3 Describe how you could measure whether your solution will reduce the impact of the natural disaster.

4 Explain how you could determine what cost (price) should be acceptable for implementing your solution.

Ideate

Once you know who you’re designing for, and you know what the criteria are, it’s time to get creative!

- Outline the criteria or requirements your designed strategy or technology must fulfil (for example, how many people will be helped, how much they will be helped, how long they will need the help).
- Brainstorm at least one idea per person that fulfils the criteria.

Remember that there are no bad ideas at this stage. One silly thought could lead to a genius innovation!

Build

Draw each design, strategy or technological idea. Label each stage of the strategy or part of the technology and how it will be used by the community.

Include in the individual strategy or technology:

a the timeline for the activation of the strategy or technology (i.e. how long after the disaster will the idea be ready to be used?)

b the number of people and materials that will be needed for the strategy or technology to reduce the impact of the natural disaster

c a description of how the community will benefit from the strategy or technology.

Present your strategy or technology to your group.

Build the prototype

Choose and build two or three versions of the prototype strategy or technology for your group design.

Use the following questions as a guideline for your prototype.

- What equipment do you have access to?
- What skills do you have, or will you need, to make your prototype strategy or technology?
- How could you model your strategy or technology if equipment is not available?
- How could you test the effectiveness of the prototype strategy or technology with the community?

Test

Use the scientific method to design an experiment that will test the effectiveness of your prototype strategy or technology. Alternatively, conduct a survey of the community to determine their opinion of the usefulness of the prototype.

Conduct your tests or survey your community, and record your results in an appropriate table.

Consider how you could use the results of the experiment or survey to modify your design.

Communicate

Present your design to the class as though you are trying to get your peers to invest in your strategy or technology.

In your presentation, you will need to:

- describe how the natural disaster will affect your community
- describe your prototype strategy or technology
- describe how the prototype will reduce the impact of the natural disaster on the community
- describe the materials, people and money that will be required to have the required effect on the natural disaster.

Check your Student obook pro for the following digital resources to help you with this STEAM project:

Student guidebook
This helpful booklet will guide you step-by-step through the project.

What is the design cycle?
This video will help you to better understand each phase in the design cycle.

How to manage your project
This 'how-to' video will help you to manage your time throughout the design cycle.

How to define a problem
This 'how-to' video will help you to narrow your ideas down and define a specific problem.

Check your Teacher obook pro for these digital resources and more:

Implementation advice
Find curriculum links and advice for this project.

Assessment resources
Find information about assessment for this project.

GLOSSARY

A

abomasum
the fourth stomach of a cow

alveoli
tiny air sacs in the lungs where gas exchange occurs

amino acids
small molecules that make up proteins

ammonia
a chemical waste product (NH_3)

amplitude
the distance a particle in a wave moves, from its position of rest

anatomy
the structure of an organism and its component parts; usually refers to human anatomy

angle of incidence
the angle between an incident ray and the normal (a line drawn at right angles to a reflective surface)

angle of reflection
the angle between a reflected ray and the normal (a line drawn at right angles to a reflective surface)

angle of refraction
the angle between a refracted ray and the normal (a line drawn at right angles to a refractive surface)

anther
the end part of a stamen (male part of a flower); contains pollen

aorta
the major artery that carries oxygenated blood from the heart and divides into smaller arteries around the body

arterioles
smaller arteries

artery
a thick, muscular-walled blood vessel that carries blood away from the heart under pressure

asthma
a disease caused by narrowing airways

atom
the smallest particle of matter; cannot be created, destroyed or broken down (indivisible)

atria
the two smaller, upper chambers of the heart

B

binary fission
a form of asexual reproduction used by bacteria; the splitting of a parent cell into two equal daughter cells

binocular
using two eyes; a type of microscope

blood
connective tissue that carries oxygen, nutrients and waste around the body

blood vessel
a tube or vessel that carries blood around the body

boiling point (BP)
the temperature at which a liquid boils and becomes a gas

bronchi
air passages that carry air in and out of the lungs; airways

C

caecum
a small dead-end pouch that connects the small and large intestines

capillary
a blood vessel with a wall only one cell thick; allows substances to pass into and out of the blood

carpel
the female reproductive organ of a flower; includes the stigma, style and ovary

catalyst
a substance that increases the rate of a chemical reaction without undergoing any permanent chemical change

cataract
a cloudiness of the eye lens

cell
(in biology) the building block of living things

cell membrane
the barrier around a cell that controls the entry and exit of substances into and out of a cell

cell theory
theory describing the properties that all cells have in common

cellular respiration
the chemical reaction between glucose and oxygen to produce carbon dioxide, water and energy

cervix
the narrow neck connecting the uterus and the vagina

chemical potential energy
energy stored in chemicals, e.g. in food, fuel or explosives; also known as chemical energy

chemical reaction
a procedure that produces new chemicals; same as chemical change

chlorophyll
a green pigment in chloroplasts that absorbs solar energy, which is used by plants in photosynthesis

chloroplast
organelle found in plant cells that transforms solar energy into chemical energy

chyme
a mixture of acid, enzymes and digested food that leaves the stomach

cleavage
the way a mineral tends to break along particular smooth planes

collision theory
a theory stating that the particles involved in a chemical reaction must collide in order to react

colour-blindness
when a person has difficulty identifying different colours; red-green colour-blindness is an inherited condition

combustion
a reaction that involves oxygen and releases light and heat energy

compound
a substance made up of two or more types of atoms bonded together (e.g. water)

compound light microscope
a microscope with two or more lenses

compression
part of a sound wave where air particles are forced close together

concave
refers to a lens or mirror that is thinner in the centre than at the ends

concentration
the number of active molecules in a set volume of solution

condense
to become a liquid, from a gas

connective tissue
the group of cells that provide connections to other parts of the body

contraception
a way of preventing pregnancy

controlled variables
variables that remain unchanged during an experiment

converge
(in relation to rays of light) to come together at a single point

convex
refers to a lens or mirror that is thicker in the centre than at the ends

corrosion
the gradual destruction of materials by a chemical reaction with their environment

corrosive
destructive to living tissues such as skin and eyes, or to some types of metals

cost–benefit analysis
a list of costs compared with benefits, usually used to analyse a proposed engineering project

critical angle
the angle of light that causes the reflected ray to move along the edge between two materials

cross-pollination
the exchange of pollen and ova between different plants of the same species

cytoplasm
the 'jelly-like' fluid inside the cell membrane that contains dissolved nutrients, waste products and organelles

D

decibel
a unit used to measure the intensity of a sound or the power level of an electrical signal

deoxyribonucleic acid (DNA)
a molecule that contains all the instructions for every job performed by the cell; this information can be passed from one generation to the next

dependent variable
a variable in an experiment that may change as a result of changes to the independent variable

desexing
a method of permanently preventing reproduction

diaphragm
a dome-shaped muscle attached to the ribs; moves up and down beneath the lungs

diarrhoea
watery faeces

diatomic molecule
a molecule that consists of two atoms

digestion
the process of breaking down food into nutrients

directly proportional relationship
a relationship between two variables in which the dependent variable increases as the independent variable increases

dispersion
the separation of white light into its different colours

dissection
the process of disassembling and studying the internal structures of plants, animals and humans

diverge
(in relation to rays of light) to move away from each other

E

elastic potential energy
the energy possessed by stretched or compressed objects

electrical energy
energy associated with electric charge, either stationary (static) or moving (current)

electromagnetic
relating to the physical interaction between moving charged particles and the magnetic field that is created as a result

electron microscope
a microscope that uses electrons (tiny negatively charged particles) to create images

emphysema
a disease caused by broken down alveoli in the lungs

endometrium
the lining of the uterus

energy efficiency
a measure of the amount of useful energy transformed in an energy transformation process; usually expressed as a percentage of the input energy (e.g. 90 per cent efficiency is very good)

enzyme
a chemical that helps make chemical reactions happen; a type of catalyst

epididymis
a coiled tube behind the testes that carries sperm to the vas deferens

epiglottis
a flap of skin above the larynx that controls the passage of food and air, preventing food from entering the windpipe

epithelial tissue
the group of cells that cover and protect the body

eukaryotic cell
complex cell that contains a nucleus and membrane-bound organelles

external fertilisation
when the egg and sperm meet outside the bodies of the parents

extrusive igneous rock
rock formed at the Earth's surface by quickly cooling lava

eyepiece
where the eyes are placed when using a microscope

F

fair testing
an experiment where only the independent variable is changed and all other variables are kept constant

fallopian tubes
tubes that connect the ovaries to the uterus

filter
a transparent material that allows only one colour of light to pass through

focal length
the distance between the centre of a lens and the focus

focus
the point where rays of light cross

foetus
an unborn animal or human after the embryo stage; in humans this is after 8 weeks of development

foliation
layering in a rock that occurs when the rock is subjected to uneven pressure

fragmentation
asexual reproduction that occurs when a new organism grows from a fragment of the parent

frequency
the number of waves that pass a point every second; measured in hertz

frost shattering
a process of weathering in which repeated freezing and melting of water expands cracks in rocks, so that eventually part of the rock splits off

G

gallstone
a hard substance or stone that is produced by the gall bladder

gamete
a sex cell; in humans, the sperm and egg cells

geologist
a scientist who studies rocks

gestation
the length of time between fertilisation and birth

gluten intolerant
unable to digest gluten

gravimeter
a device that measures the difference in gravity between one location and the next

gravitational potential energy
the energy possessed by an object raised to a height in a gravitational field

greenhouse gas
a gas (carbon dioxide, water vapour, methane) in the atmosphere that can absorb heat

group
a vertical list of elements in the periodic table that have characteristics in common

H

hardness
how easily a mineral can be scratched; measured using the Mohs hardness scale

hazard
something that has the potential to put a person's health and safety at risk

hermaphrodite
an organism that has both male and female reproductive systems

hertz
the unit used to measure frequency

hyperopia
long-sightedness; when a person has difficult seeing close objects

I

igneous rock
rock formed by cooling magma and lava

image
a likeness of an object that is produced as a result of light reflection or refraction

inbreeding
breeding of animals that are related, increasing the chances of genetic abnormalities appearing

independent variable
a variable (factor) that is changed in an experiment

index mineral
a mineral that only forms at a particular temperature and pressure; used to determine the history of the rock that contains the mineral

infectious disease
disease caused by the passing of a pathogen from one organism to another; also known as contagious disease

inhale
breathe in

internal fertilisation
when the sperm fertilises the egg inside the body of an organism

intrusive igneous rock
rock formed underground by slowly cooling magma

inversely proportional relationship
a relationship between two variables in which the dependent variable decreases as the independent variable increases

L

lattice
a three-dimensional arrangement of particles in a regular pattern

lava
hot, molten rock that comes to the surface of the Earth in a volcanic eruption

law of conservation of energy
a scientific rule that states that the total energy is always constant and cannot be created or destroyed

longitudinal wave
a type of (sound) wave where the particles move in the direction of travel of the wave

long-sighted
when a person has difficulty seeing close objects

lustre
the shininess of a mineral

M

magma
semiliquid rock beneath the Earth's surface

magnetometer
a device that detects the difference in magnetic field between one location and the next

medium
a substance or material through which light can move

melt
change state from solid to liquid

menstruation
also known as a period; the process of the endometrial lining of the uterus breaking down and leaving the vagina

metabolism
all the chemical reactions in the body

metamorphic rock
rock formed from other rock due to intense heat and pressure

microbes
living things that can only be seen with the use of a microscope; a micro-organism

microbiology
the science involving the study of microscopic organisms

micro-organism
a microscopic organism

microscope
an instrument with lenses that is used for viewing very small objects

microscopy
the study of living things that can only be seen with the use of a microscope

minerals
tiny grains or crystals that are the building blocks of rocks

mitochondrion
powerhouse organelle of a cell; the site of energy production; plural (plural: mitochondria)

mixture
a substance made up of two or more pure substances mixed together

molecular compound
a molecule that contains two or more different atoms bonded together

molecular element
a molecule that contains two or more of the same atoms bonded together

molecule
group of two or more atoms bonded together (e.g. a water molecule)

monatomic
consisting of a single atom

monocular
using one eye; a type of microscope

motion
when an object changes its position over time

multicellular
an organism that has two or more cells

muscle tissue
the group of cells that allow the body to move

myopia
short-sightedness; when a person has trouble seeing objects in the distance

N

natural flora
microbes that live happily in our bodies

nephrons
tiny structures in the kidneys that filter the blood

nervous tissue
the group of cells that pass on electrical messages

normal
(in relation to light) an imaginary line drawn at right angles to the surface of a reflective or refractive material

nuclear energy
energy stored in the nucleus of an atom and released in nuclear reactors or explosions of nuclear weapons; much greater than the chemical energy released in chemical reactions

nucleus
control centre of a cell that contains all the genetic material (DNA) for that cell

O

objective lens
lens in the column of a compound light microscope

oestrogen
a reproductive hormone in females

offspring
an organism's young, or child

omasum
the third stomach of a cow

onion-skin weathering
weathering of rock where the outside of the rock peels off

opaque
not allowing light to pass through

optic fibre
a thin fibre of glass or plastic that carries information/data in the form of light

organ
a group of tissues that work together for a purpose

organelle
smaller part of a cell, each one having a different function

osmosis
the movement of water through a selective membrane from an area of low 'salt' concentration to an area of high 'salt' concentration; occurs in root cells

ovary
the female organ that produces eggs

oviduct
the tube through which eggs travel from the ovary

ovulation
the part of the menstrual cycle when an egg is released from the ovary

ovum
the reproductive egg

P

parthenogenesis
asexual reproduction where a female fertilises her own eggs

pathogen
microbe that can potentially cause a disease

period
(in chemistry) a horizontal list of elements in the periodic table

periodic table
a table in which elements are listed in order of their atomic number, and grouped according to similar properties

peristalsis
the process of swallowed food being moved along the digestive tract by a wave of contractions, as the muscles behind the food squeeze tight and the muscles in front of the food relax, causing the food to move along the oesophagus or intestines

pharynx
the throat; connects the mouth to the oesophagus

phloem
the vascular tissue in plant stems that carries sugars around the plant

photosynthesis
chemical process plants use to make glucose and oxygen from carbon dioxide and water

photovoltaic cell (PVC)
an electrical device that converts light energy into electrical energy; see solar cell

placenta
the organ that connects the developing foetus to its mother

plasma
a straw-coloured fluid that forms part of the blood

platelets
small disc-like cells in blood that are involved in forming clots

pneumonia
a disease caused by bacterial or viral growth in the lungs

pollination
fertilisation of gametes in plants

polymer
a long-chain molecule formed by the joining of many smaller repeating molecules (monomers)

primary colours of light
the three colours of light (red, blue and green), which can be mixed to create white light

product
a substance obtained at the end of a chemical reaction; written on the right side of a chemical equation

prokaryotic cell
primitive single-celled organism that has no nucleus

properties
in chemistry, the characteristics or things that make a substance unique

prostate gland
a walnut-sized structure surrounding the neck of the male bladder that blocks the flow of urine so sperm can move along the urethra

pure substance
something that contains only one type of substance (e.g. a single element or a single compound)

R

rarefaction
a reduction in density; refers to part of a sound wave where air particles are forced apart

reactant
a substance used at the beginning of a chemical reaction; written on the left side of a chemical equation

red blood cell
cell in the blood that carries oxygen around the body

refracted ray
a ray of light that has bent as a result of speeding up or slowing down when it moves into a more or less dense medium

refraction
the bending of light as a result of speeding up or slowing down when moving into a medium of different density

refractive index
a measure of the bending of light as it passes from one medium to another

remote control
an electronic device used to operate a machine remotely (i.e. at a distance)

reticulum
the second stomach of a cow

ribosome
cell organelle where protein production takes place

rock cycle
the process of formation and destruction of different rock types

root
a plant organ involved in absorbing nutrients and water

rumen
the first stomach of a cow

S

scrotum
a sac-like structure that contains the testes

secondary colours of light
the colours of light (magenta, cyan and yellow) that result from the mixing of two primary colours of light

sedimentary rock
rock formed from compacted mud, sand or pebbles, or the remains of living things

seismic geophysical testing
the collecting of geophysical data such as differences in magnetic fields and gravity fields between different geological locations

self-pollination
when both gametes come from the same plant

seminal vesicles
a pair of small pouch-like structures that provide a sugary fluid that assists sperm to travel along the vas deferens

sexually dimorphic
describes species in which the male and female organisms look structurally different

short-sighted
when a person has difficulty seeing distant objects

single-celled
an organism that consists of one cell

solar cell
a device that transforms sunlight directly into electrical energy; is usually in the form of a panel; also known as a solar panel

sound energy
a type of kinetic energy produced when things vibrate, causing waves of pressure in the air or some other medium

spore
a tiny reproductive structure that, unlike a gamete, does not need to fuse with another cell to form a new organism

stain
substance, such as iodine, used to make cells more visible under a microscope

stem
an organ that transports materials around the plant

stereomicroscope
a microscope with two eyepieces that uses low magnification

stigma
the male part of a plant, consisting of a filament supporting an anther

streak
the colour of a powdered or crushed mineral

sublimation
a change of state from a solid directly to a gas

surface area to volume ratio
the relationship between the area around the outside of a cell and its volume, as a fraction

symptoms
the physical or mental signs of a disease

system
a group of organs that work together for a purpose

T

testis
the male reproductive organ that produces sperm (plural: testes)

testosterone
a male hormone involved in the reproductive system

thermal energy
the scientific term for heat energy

tor
a large, round rock produced by onion-skin weathering

total internal reflection
the complete reflection of a light ray when it passes from a more dense to a less dense material at a large angle; the ray is reflected back into the dense medium

trachea
the large tube that connects the throat to the bronchi; carries air in and out of the body

transferred
describes energy that has moved from one object to another

transformed
describes energy that has changed into a different form

translucent
allowing light through, but diffusing the light so objects cannot be seen clearly

transmit
to allow light to pass through

transparent
allowing all light to pass through, so objects can be seen clearly

transpiration
the process of water evaporating from plant leaves; causes water to move up through the plant from the roots

transverse wave
a type of (light) wave where the vibrations are at right angles to the direction of the wave

U

ulcer
an open sore on the inside or the outside of the body

ultrasound
a way sound can be used to identify tissue or to shatter stones

unicellular
living things consisting of only one cell (e.g. bacteria)

urea
a chemical waste product produced by the body and removed in the urine

uterus
an organ in the female reproductive system; where the foetus develops

V

vagina
a female reproductive organ; a muscular tube connecting the outside of the female body to the cervix

vaporise
change state from a liquid to a gas; evaporate

vapour
gaseous form of a substance that is normally solid or liquid at room temperature (e.g. water vapour)

variable
something that can affect the outcome or results of an experiment

vas deferens
the tube through which sperm travel from the epididymis to the prostate

vascular bundle
a group of tubes in plant stems that carry water and nutrients around the plant

vegetative reproduction
a type of asexual reproduction where part of a plant breaks off, forming a new organism with no need for seeds or spores; similar to fragmentation

vein
a thin-walled blood vessel that carries blood back to the heart

ventricles
the two large lower chambers of the heart

villi
small ridges in the small intestine that absorb nutrients from the digestive system

virtual image
an image that appears in a mirror; it cannot be captured on a screen

visible spectrum
the variety of colours of wavelengths of light that can be seen by the human eye

volatile
describes a substance that easily becomes a gas

W

wavelength
the distance between two crests or troughs of a wave

white blood cell
an immune system cell that destroys pathogens

X

xylem
the tissue in plants that carries water from the roots to the rest of the plant

Z

zygote
a fertilised egg

INDEX

Notes

The Grampians National Park in Victoria provides scientists with information about the Victorian landscape. This image shows a geologist observing rock formations that have been shaped over millions of years. The Grampians National Park has mountain ranges formed of sandstone and dramatic granite outcrops. Known as *Gariwerd* to the local Aboriginal peoples, the site is also renowned for its rock art.

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