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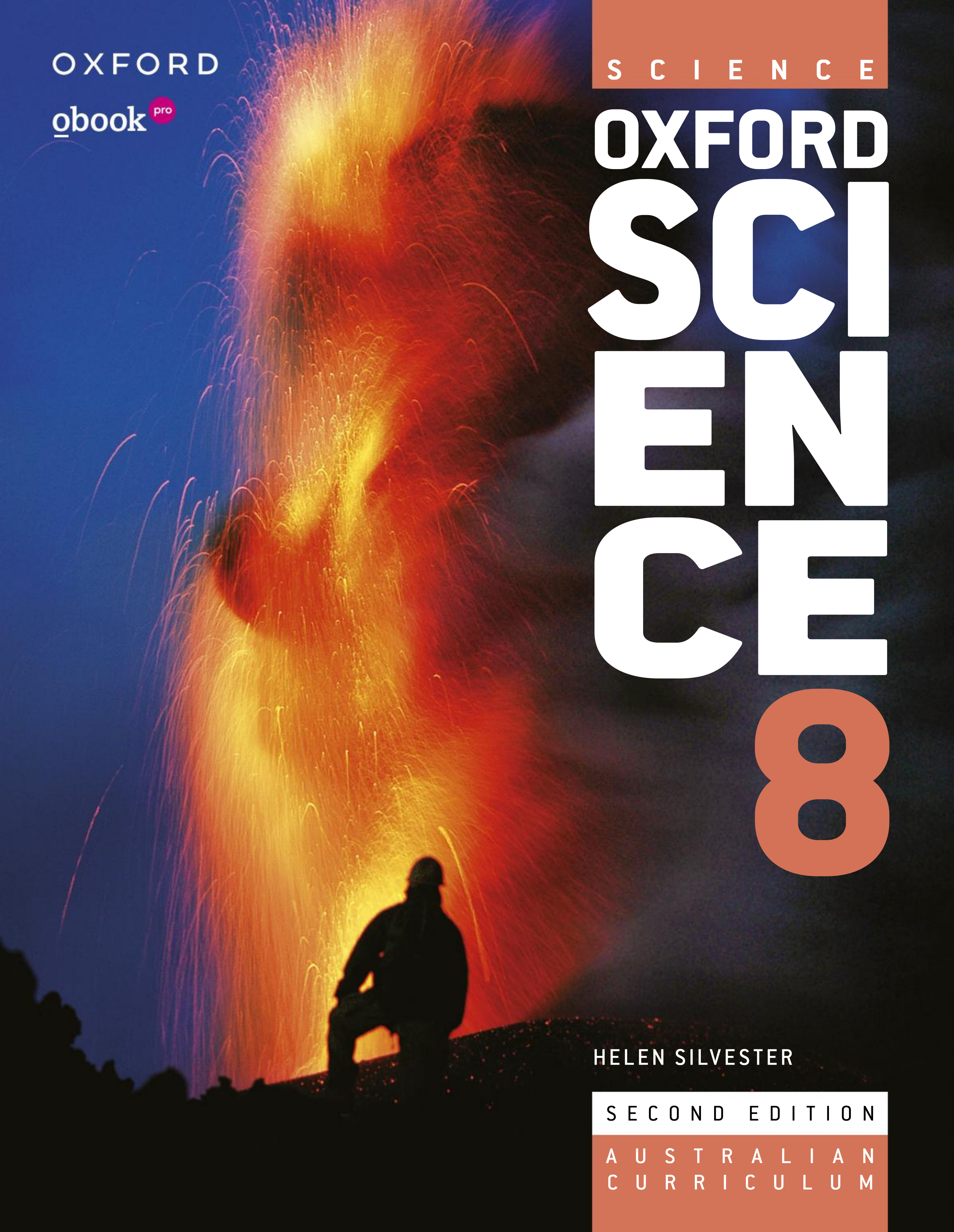


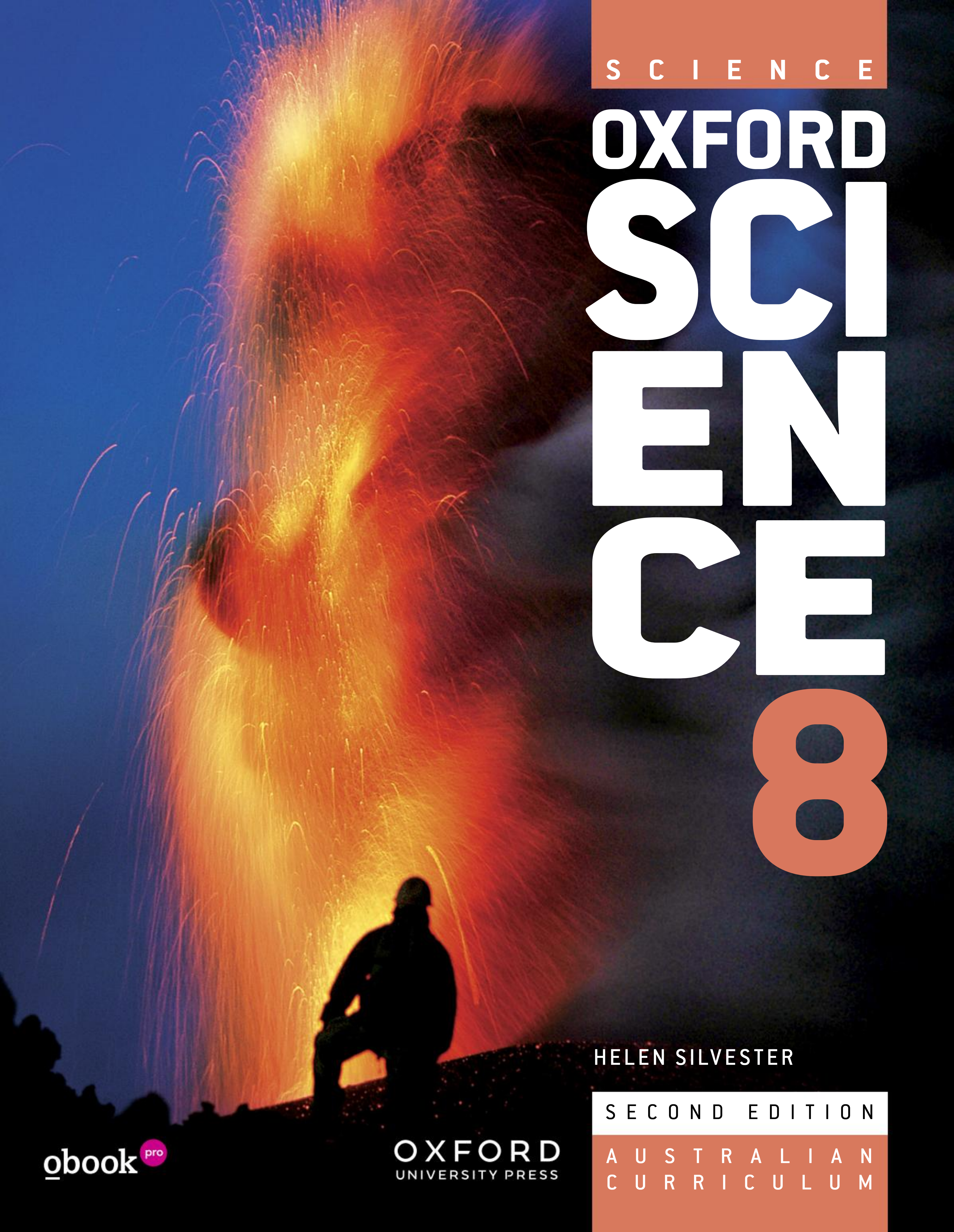
SCIENCE

OXFORD SCIENCE 8

HELEN SILVESTER

SECOND EDITION

AUSTRALIAN CURRICULUM



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OXFORD UNIVERSITY PRESS

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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 to plan and conduct investigations. They aim to avoid experimental errors and they record the details of their work in an experimental logbook. Scientists present and interpret their data accurately.

2

The rock cycle

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

3

Plate tectonics

Plate tectonics is a combination of two theories: continental drift and sea-floor spreading. Plate tectonics explains global patterns of geological activity and the movement of the continents.

4

Energy

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

5

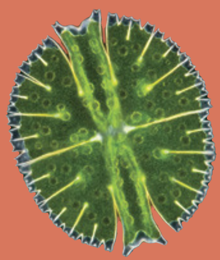
Physical and chemical change

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

Experiments

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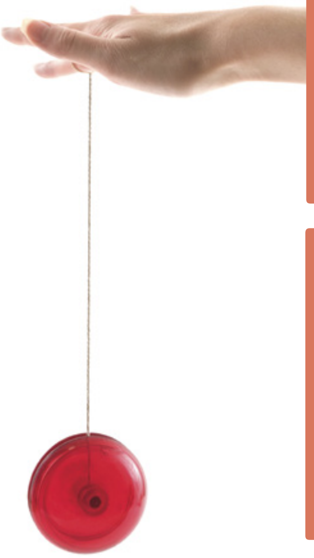
CONTENTS



INTRODUCING *OXFORD SCIENCE 7–10 AUSTRALIAN CURRICULUM*

Oxford Science Australian Curriculum has been developed to meet the requirements of the *Australian 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 in the senior secondary years.

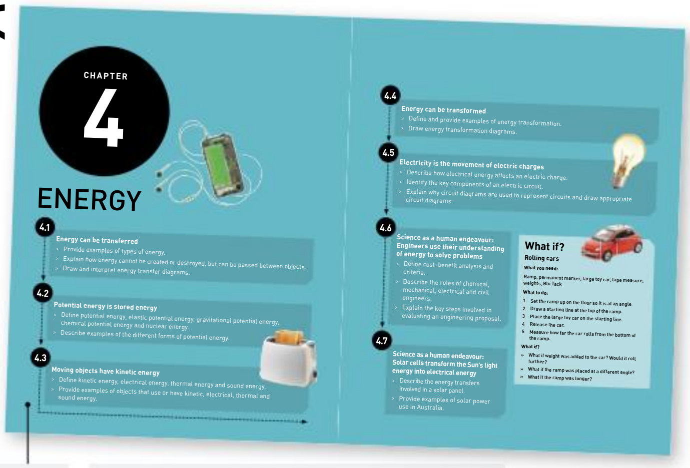
The series offers a completely integrated suite of print and digital resources to meet your needs, including:

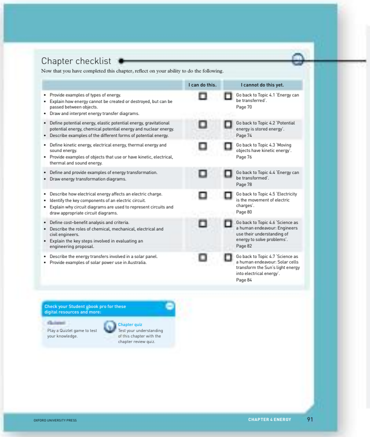
- Student Book
- Student obook pro
- Teacher obook pro.

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





Reflect

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

Chapter openers

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

Concept statements

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

Learning intentions

- Learning intentions are clearly stated for every topic.

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 the learning intentions for the topic. Questions are phrased using bolded cognitive verbs, which state what is expected of a student and prepares them for studying senior science subjects.

Focus on science inquiry skills and capabilities

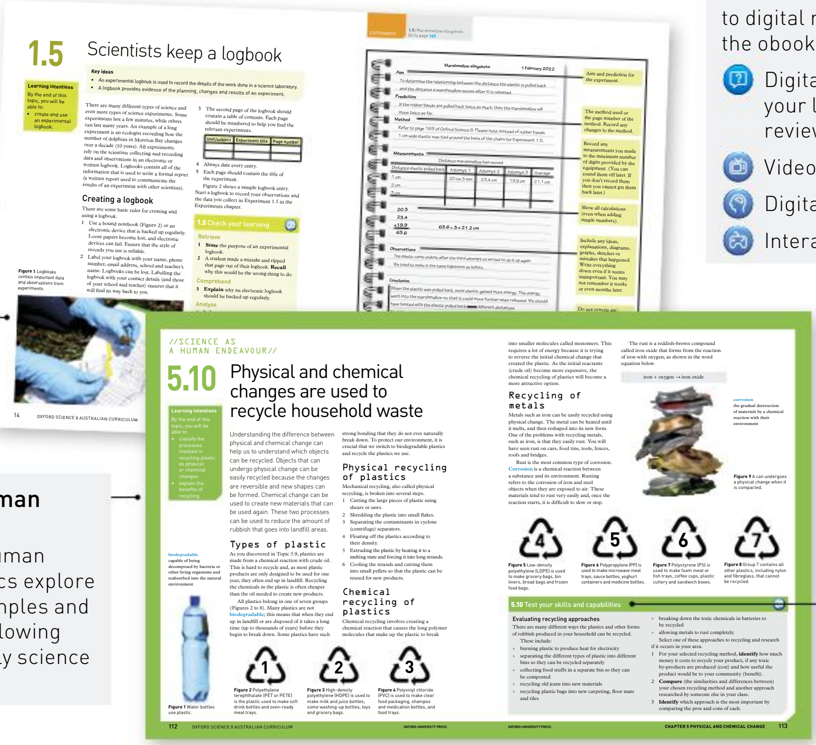
Digital hotspots

Icons found in the student book link to digital resources accessible via the obook pro

- Digital versions of the Check your learning and Chapter review questions
- Videos
- Digital quizzes
- Interactives

Science toolkit

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


1.5 Scientists keep a logbook

//SCIENCE AS A HUMAN ENDEAVOUR//

5.10 Physical and chemical changes are used to recycle household waste

Science as a human endeavour

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

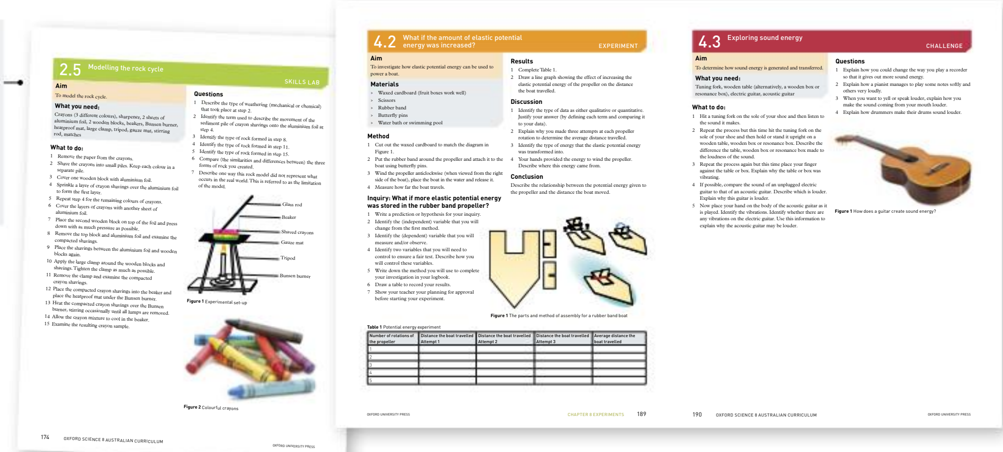
Test your skills and capabilities

- This section provides 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.


2.5 Modelling the rock cycle

4.2 What if the amount of elastic potential energy was increased?

4.3 Exploring sound energy

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.


[STEAM project 1]

How can we build more energy-efficient homes so that we live more sustainably?

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.

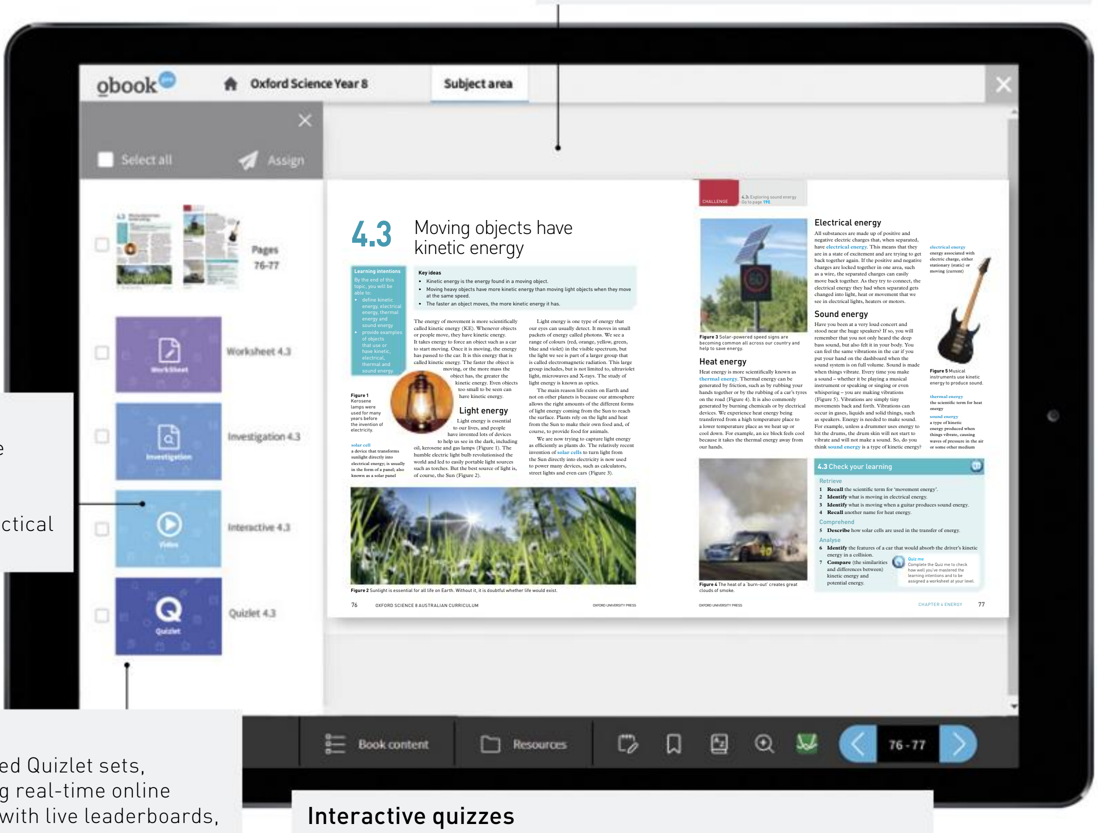
Key features of Student obook pro

- 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 provide a mix of auto- and teacher-corrected questions, 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.

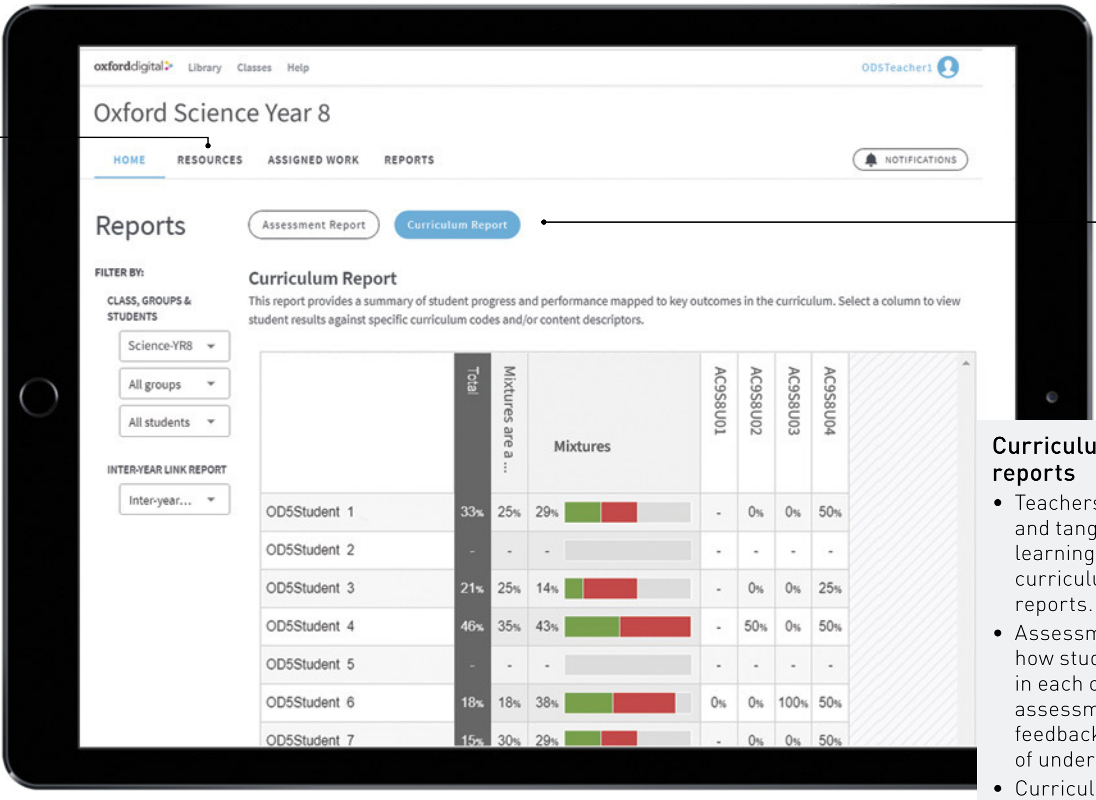
Key features of Teacher obook pro

- 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.



Oxford Science Year 8

Reports

Curriculum Report

This report provides a summary of student progress and performance mapped to key outcomes in the curriculum. Select a column to view student results against specific curriculum codes and/or content descriptors.

	Total	Mixtures are a ...	Mixtures	AC9S8U01	AC9S8U02	AC9S8U03	AC9S8U04
OD5Student 1	33%	25%	29%	-	0%	0%	50%
OD5Student 2	-	-	-	-	-	-	-
OD5Student 3	21%	25%	14%	-	0%	0%	25%
OD5Student 4	46%	35%	43%	-	50%	0%	50%
OD5Student 5	-	-	-	-	-	-	-
OD5Student 6	18%	18%	38%	0%	0%	100%	50%
OD5Student 7	15%	30%	29%	-	0%	0%	50%

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 descriptions 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.

AUSTRALIAN CURRICULUM: SCIENCE 8 SCOPE AND SEQUENCE

YEAR 8 DESCRIPTION

In Year 8, students are introduced to cells as microscopic structures that explain macroscopic features of living systems. They connect form and function at an organ level and explore the organisation of a body system in terms of flows of matter between interdependent organs. They continue to develop a view of Earth as a dynamic system, in which change occurs across a range of timescales. They classify different types of energy and describe the role of energy in causing change in systems, including the role of energy and forces in the geosphere. They learn to classify matter at the atomic level and distinguish between chemical and physical change. They understand that chemical reactions also involve energy. Students use experimentation to isolate relationships between components in systems and explain these relationships through increasingly complex representations. They consider the magnitude of properties and events and use appropriate units to describe proportional relationships.

YEAR 8 CONTENT DESCRIPTIONS	
SCIENCE UNDERSTANDING	
Biological sciences	
Chapter 6	Recognise cells as the basic units of living things, compare plant and animal cells, and describe the functions of specialised cell structures and organelles (AC9S8U01)
Chapter 7	Analyse the relationship between structure and function of cells, tissues and organs in a plant and an animal organ system and explain how these systems enable survival of the individual (AC9S8U02)
Earth and space sciences	
Chapter 2	Investigate tectonic activity including the formation of geological features at divergent, convergent and transform plate boundaries and describe the scientific evidence for the theory of plate tectonics (AC9S8U03)
Chapter 3	Describe the key processes of the rock cycle, including the timescales over which they occur, and examine how the properties of sedimentary, igneous and metamorphic rocks reflect their formation and influence their use (AC9S8U04)
Physical sciences	
Chapter 4	Classify different types of energy as kinetic or potential and investigate energy transfer and transformations in simple systems (AC9S8U05)
Chemical sciences	
Chapter 5	Classify matter as elements, compounds or mixtures and compare different representations of these, including 2-dimensional and 3-dimensional models, symbols for elements and formulas for molecules and compounds (AC9S8U06)
Chapter 5	Compare physical and chemical changes and identify indicators of energy change in chemical reactions (AC9S8U07)
SCIENCE AS A HUMAN ENDEAVOUR	
Nature and development of science	
All chapters	Explain how new evidence or different perspectives can lead to changes in scientific knowledge AC9S8H01
All chapters	Investigate how cultural perspectives and world views influence the development of scientific knowledge (AC9S8H02)
Use and influence of science	
All chapters	Examine how proposed scientific responses to contemporary issues may impact on society and explore ethical, environmental, social and economic considerations (AC9S8H03)
All chapters	Explore the role of science communication in informing individual viewpoints and community policies and regulations (AC9S8H04)

SCIENCE INQUIRY	
Questioning and predicting	
All chapters	Develop investigable questions, reasoned predictions and hypotheses to explore scientific models, identify patterns and test relationships (AC9S8I01)
Planning and conducting	
All chapters	Plan and conduct reproducible investigations to answer questions and test hypotheses, including identifying variables and assumptions and, as appropriate, recognising and managing risks, considering ethical issues and recognising key considerations regarding heritage sites and artefacts on Country/Place (AC9S8I02)
All chapters	Select and use equipment to generate and record data with precision, using digital tools as appropriate (AC9S8I03)
Processing, modelling and analysing	
All chapters	Select and construct appropriate representations, including tables, graphs, models and mathematical relationships, to organise and process data and information (AC9S8I04)
All chapters	Analyse data and information to describe patterns, trends and relationships and identify anomalies (AC9S8I05)
Evaluating	
All chapters	Analyse methods, conclusions and claims for assumptions, possible sources of error, conflicting evidence and unanswered questions (AC9S8I06)
All chapters	Construct evidence-based arguments to support conclusions or evaluate claims and consider any ethical issues and cultural protocols associated with using or citing secondary data or information (AC9S8I07)
Communicating	
All chapters	Write and create texts to communicate ideas, findings and arguments for specific purposes and audiences, including selection of appropriate language and text features, using digital tools as appropriate (AC9S8I08)

YEAR 8 ACHIEVEMENT STANDARD

By the end of Year 8, students explain the role of specialised cell structures and organelles in cellular function and analyse the relationship between structure and function at organ and body system levels. They apply an understanding of the theory of plate tectonics to explain patterns of change in the geosphere. They explain how the properties of rocks relate to their formation and influence their use. They compare different forms of energy and represent transfer and transformation of energy in simple systems. They classify and represent different types of matter and distinguish between physical and chemical change. Students analyse how different factors influence development of and lead to changes in scientific knowledge. They analyse the key considerations that inform scientific responses and how these responses impact society. They analyse the importance of science communication in shaping viewpoints, policies and regulations.

Students plan and conduct safe, reproducible investigations to test relationships and explore models. They describe potential ethical issues and intercultural considerations needed for specific field locations or use of secondary data. They select and use equipment to generate and record data with precision. They select and construct appropriate representations to organise and process data and information. They analyse data and information to describe patterns, trends and relationships and identify anomalies. They identify assumptions and sources of error in methods and analyse conclusions and claims with reference to conflicting evidence and unanswered questions. They construct evidence-based arguments to support conclusions and evaluate claims. They select and use language and text features appropriately for their purpose when communicating their ideas, findings and arguments to specific audiences.

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CHAPTER

1

SCIENCE TOOLKIT

1.1

Scientists ask questions

> Describe a relationship between two sets of data.

> Develop investigable questions, reasoned predictions and hypotheses.

1.2

Scientists must be aware of experimental errors

> Explain the importance of minimising experimental errors.

> Identify experimental errors and numbers of significant figures.

> Use rounding off techniques, the SI system and derived units.

1.3

Tables and graphs are used to present scientific data

> Interpret data in tables and on line graphs.

> Identify and describe directly proportional and inversely proportional relationships on line graphs.

1.4

Scientists present their data accurately

> Explain outliers in data and how to deal with them.

> Identify the median in a data set.

> Calculate the mean and mode of a data set.

1.5

Scientists keep a logbook

> Create and use an experimental logbook.

1.6

Cognitive verbs identify the tasks in a question

> Recognise the cognitive verb in a question.

> Understand the different tasks involved for different cognitive verbs.

What if?

Observations

What you need:

A4 paper, notebook, pen

What to do:

1 Look around your classroom for 30 seconds.

2 Look down at your notebook and write a description of all the things you observed.

3 Check your answers. How many things did you observe?

What if?

» What if you had more time to observe the classroom?

» What if you knew that you had to write an observation list before you looked around the room?

» What if you repeated the test?

1.1 Scientists ask questions

Key ideas

- Causation occurs when the independent variable is responsible for the change in the dependent variable.
- Two things are correlated when they both change in a related way.
- Positive correlation of data does not mean one event causes another event.

Learning intentions

By the end of this topic, you will be able to:

- describe a relationship between two sets of data
- develop investigable questions, reasoned predictions and hypotheses.

All scientists are curious about the world they live in. They use all of their senses to observe small changes and try to explain why these changes occur by asking what caused the change.

While this might seem a simple question, if the scientist does not plan a **valid experiment**, they may end up with misleading results. For example, a scientist may notice that there is a larger number of shark attacks in summer than winter. They may also notice that the number of ice creams sold by a kiosk on the beach also increases in summer. During winter, both ice-cream sales and shark attacks go down. If this is graphed (Figure 1), it could look like the ice-cream sales caused the shark attacks because they both go up at the same time. This is not correct as there is another causative factor: hot weather. In hot weather, more people go swimming and shark attacks are more likely to occur than in cold weather when few people go into the ocean. People are also more likely to buy ice creams in summer than winter. The hot weather is the cause of the increased shark attacks and ice-cream sales. A scientist would describe the relationship between the shark attacks and ice-cream sales as a **correlation** (when two or more things are related).

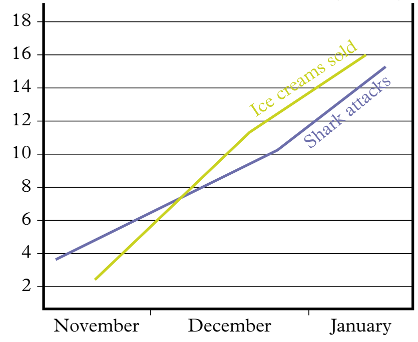


Figure 1 There is a positive correlation between the number of ice creams sold and the number of shark attacks.

valid experiment	where an experiment investigates what it sets out to investigate
correlation	a relationship between two or more things
causation	when the independent variable is responsible for the change in the dependent variable

Correlation of data

When two sets of data are strongly linked (as one changes, the other changes by a similar amount), the data has a strong correlation. When both values increase at the same rate, it is called a positive correlation. If one value increases as the other decreases, then it has a negative correlation. This can be shown on a graph (Figure 2).

Correlation shows that there is a relationship between the two variables; it does not necessarily mean that one variable causes the other to change (that is **causation**).

Reproducible

To identify if a relationship is causal or a correlation, scientists need to design a reproducible experiment. This means the experiment can be repeated using the same materials and measurement, and exactly the same results will be recorded.

Balloon rockets

Before continuing, complete Experiment 1.1A in the Experiments chapter.

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?

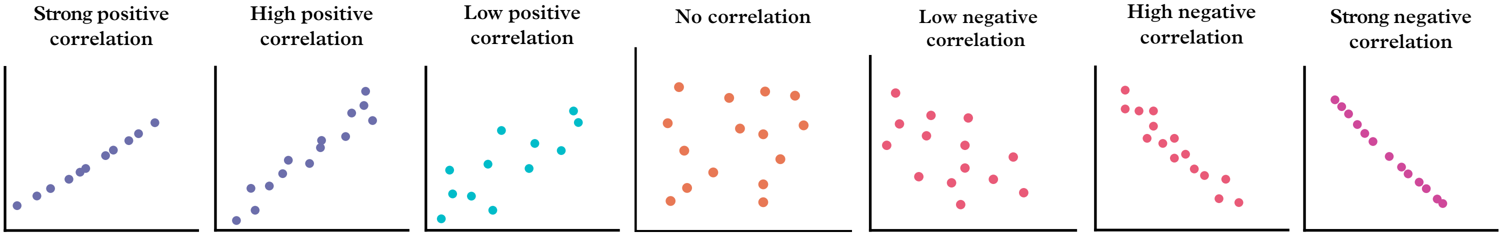


Figure 2 Correlation of data

EXPERIMENT

1.1A: Making a balloon rocket
Go to page **166**.

EXPERIMENT

1.1B: Changing the independent variable
Go to page **167**.

Each of these questions ask what would happen if the **independent variable** were increased or decreased. In a reproducible experiment 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 needs to be a **reasonable experiment** and 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.

A **hypothesis** describes the expected relationship between the independent variable and the dependent variable and the scientific reasoning that is used. The process for converting a 'what if' question to a hypothesis is shown in Figure 3.

Now try changing the independent variable in Experiment 1.1B in the Experiments chapter.

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

reasonable experiment
a test where all variables are controlled except for the one being changed on purpose

hypothesis
a proposed explanation for a prediction that can be tested

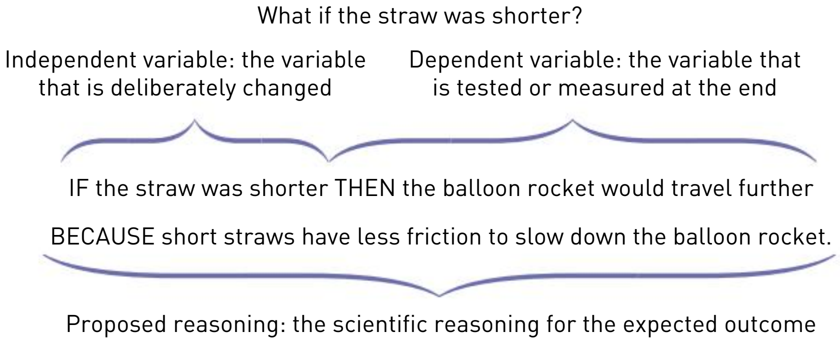


Figure 3 A 'what if' question can be changed into a hypothesis by removing the 'what' at the start, adding a 'then' at the end of the question and a 'because' to explain the related science concept.

1.1 Check your learning

Retrieve

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

Comprehend

2 **Describe** the relationship between the sets of data shown in Figure 4.

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

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

Analyse

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

Apply

6 **Discuss** why it is important for experimental methods to be checked by other scientists.

7 Many experimental reports written by scientists are peer reviewed. **Investigate** what is meant by 'peer reviewed' and write a definition in your own words.

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

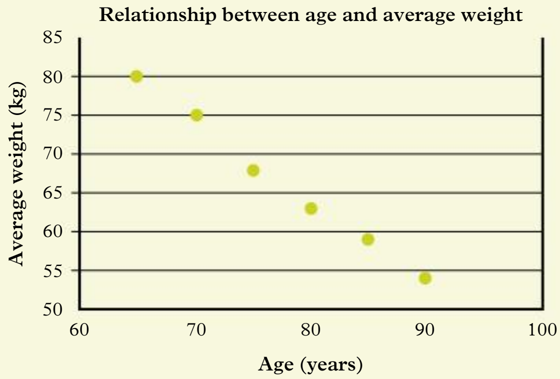


Figure 4 A scatterplot showing the relationship between age and average weight

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 …

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

1.2 Scientists must be aware of experimental errors

Learning intentions

By the end of this topic, you will be able to:

- explain the importance of minimising experimental errors
- identify experimental errors and numbers of significant figures
- use rounding off techniques, the SI system and derived units.

accuracy
how carefully, correctly and consistently data has been measured or processed; in science, how close a measured value is to the true value

reading error
an error that occurs when markings on a scale are not read correctly

parallax error
an error, or inaccurate reading, that occurs as a result of reading a scale from an angle

zero error
an error that occurs when an instrument has not been adjusted to zero before the measurement is taken

Key ideas

- To achieve maximum accuracy, the measurement must be taken carefully, using the most suitable measuring device.
- Each scientific device must have a scale appropriate to the accuracy that you require.

Choosing the right device

Choosing the right instrument is the first step in making sure measurements are **accurate** (close to the expected true value). For example, if you needed to accurately measure the volume of a liquid, then you would use a burette (Figure 1) or a measuring cylinder, but not a beaker. A burette has a more accurate scale than a measuring cylinder. Both are carefully checked during the manufacturing process; however, a burette has smaller units that can be controlled by the scientist. A beaker often has no scale.

Figure 1 A burette is a laboratory instrument used to accurately measure the volumes of liquids.

Errors and accuracy

Choosing the right instrument is only part of a scientist's job. It is very important to take care with your measurements.

The most common errors in measurement are **reading errors**, **parallax errors** and **zero errors**.

A reading error can result when guesswork is involved when taking a reading. For example, when reading lines between the divisions on a scale, an estimate of the actual reading can result in a reading error.

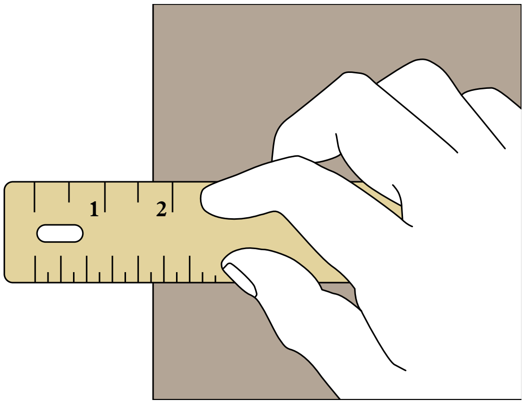


Figure 2 Estimating the measurement between units of measurement (for example, between 1.6 and 1.8) can produce a reading error.

The possibility of a reading error can be recorded in the data by noting the possible range. For example, if you were reading the marks on a ruler (Figure 2), you might estimate that the reading was somewhere between 1.6 and 1.8. This can be recorded as 1.7.

A parallax error occurs when the eye is not directly opposite the scale when the reading is being taken. You can avoid parallax errors by making sure that your eye is in the correct position when taking the reading. For example, when reading the level of a liquid in a measuring cylinder, place the cylinder on the bench and line up your eye with the bottom of the meniscus (Figure 3).

CHALLENGE

1.2: Avoiding errors and improving accuracy
Go to page **168**.

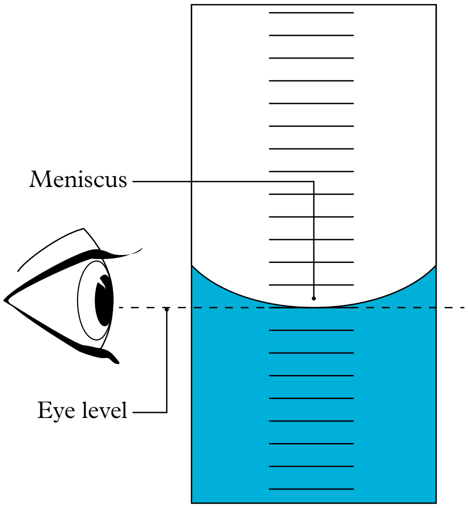


Figure 3 To avoid parallax error, make sure your eye is correctly lined up with the bottom of the meniscus.

A zero error happens when an instrument has not been correctly adjusted to zero or the reading has not taken into account the weight of empty containers. For example, scales must be set to zero correctly before making a weight measurement of substances (Figure 4).

Figure 4 Scales must be zeroed correctly before using them.

To check the accuracy of digital scales, scientists use a special mass that is known to be exact. When this is placed on the scale, the weight shown by the scale is compared to the known true mass. If they are the same, then the scale is accurate.

Mathematical accuracy

When conducting a scientific investigation, mathematical accuracy is very important. Not only must your equipment be appropriate and precise to avoid errors, but your calculations must also be correct.

When taking a reading, you should quote the maximum allowed number of **significant figures** (the number of digits). This can represent the accuracy of a measurement or reading. When recording results, it is important to know the number of significant figures the instrument allows. When adding or subtracting numbers, the final answer will be based on the least number of decimal places. When multiplying or dividing numbers, the final answer can only be quoted correct to the number of significant figures in the least accurate result. For example, if one measuring device measures 10.22 (four significant figures and two decimal places) and a second device measures 20.345 (five significant figures and three decimal places), averaging these results means adding the values. This means the final answer should only have two figures after the decimal point. This might require a **rounding off** procedure.

significant figures
the number of digits that contribute to the overall value of a number

rounding off
reducing the number of significant figures by increasing or decreasing to the nearest significant figure; for example, 7.6 cm is rounded up to 8 cm, 7.2 cm is rounded down to 7 cm

Note that when a number ends in a zero (6.0), the final zero does not contribute to the actual value of the number. This means there is no difference between 9.0 and 9. When this occurs, the number is described as having one significant figure.

Worked example 1.2: Significant figures

A student used two sets of scales to measure 0.44 g of sand and 0.696 g of water. Calculate the final mass when the sand was mixed with the water. Give your answer to an appropriate number of significant figures.

Solution

Add the mass of the sand and water together.

$$0.44 + 0.696 = 1.136\,\text{g}$$

As one number has only two decimal places, the final answer must have two decimal places. The number (1.136) is closer to 1.14 than to 1.13, so 1.14 is more accurate.

Final mass of sand and water = 1.14 g

SI system
an international system of measurement based on the metric system, with units such as kilogram, metre, kilometre

derived units
units of measurement that are calculated using a combination of SI (international system) base units, e.g. cm^3 for volume (base unit is cm), m^2 for area (base unit is m)

Measurements and units

Scientists measure fundamental quantities, such as mass, time and length, in a standard unit that has been agreed upon by scientists around the world. The international system of units, known as the **SI system** of units, is based on the metric system. Table 1 shows some SI units. Other measurements, such as volume, are calculated from those basic units and are called **derived units**.

Although the SI unit for mass is the kilogram, this is not always the most suitable unit to use. Some objects are too heavy or too light for this to be the most convenient unit. The measurement would have too many zeroes in it. For example, a mass of 0.000 000 007 43 kg or 850 000 000 kg is very inconvenient to write. Scientists and mathematicians choose a unit that requires as few zeroes as possible. They use a system of prefixes before the basic measurement unit, shown in Table 2.

Notice that when the number is larger than the basic measurement, the symbol for the prefix is a capital letter. When it is only a fraction of the basic measurement, the symbol for the prefix is a small letter (i.e. lower case). For example, a megalitre, which is a million litres, is written as ML, while a millilitre, which is one-thousandth of a litre, is written as mL. 'Kilo' is an exception to this general rule. A kilogram is 1000 grams and its symbol is kg.

Table 1 SI units

Physical quantity	SI unit	Abbreviation or symbol
length	metre	m
volume	litre	L
mass	kilogram	kg
time	second	s
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
electric current	ampere	A

Table 2 Standard prefixes and meanings

Prefix	Symbol	Value	Meaning
peta	P	10^{15}	one quadrillion (one thousand million million)
tera	T	10^{12}	one trillion
giga	G	10^{9}	one billion
mega	M	10^{6}	one million
kilo	k	10^{3}	one thousand
centi	c	10^{-2}	one-hundredth
milli	m	10^{-3}	one-thousandth
micro	μ	10^{-6}	one-millionth
nano	n	10^{-9}	one-billionth
pico	p	10^{-12}	one-millionth of one million

Figure 5 It is important to take care with your measurements to avoid errors.

1.2 Check your learning

Retrieve

1 **Recall** three kinds of errors that can occur during an experiment.

Comprehend

2 **Describe** how these errors can be reduced to improve accuracy.

Analyse

3 **Compare** (the similarities and differences between) a reading error and a parallax error.

4 **Identify** the symbol for:
  - **a** millionths of a gram
  - **b** billions of litres
  - **c** thousandths of an ampere
  - **d** thousands of metres.

5 **Identify** the number of significant figures in each of the following measurements.
  - **a** 45.22 mL
  - **b** 9.0 s
  - **c** 8000 L
  - **d** 3.005 m

Apply

6 A student took the following measurements during an experiment:

5.6 volts, 2.97 amperes, 3000 seconds.

If these three numbers were used in a calculation, **identify** how many significant figures should be stated in the final answer. **Justify** your answer (by explaining how you made your decision).

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

1.3 Tables and graphs are used to present scientific data

Learning intentions

By the end of this topic, you will be able to:

- interpret data in tables and on line graphs
- identify and describe directly proportional and inversely proportional relationships on line graphs.

Key ideas

- Tables are used to present data.
- Graphs are a way to display the information (data) gathered in an experiment.
- Graphs can be used to identify patterns in the data.

Collecting data

One of the easiest ways to record data is in a table or an electronic spreadsheet. Using a table to show large amounts of data can make it easier to see patterns and relationships between the variables (Figure 1). A table should have a title which describes the information that is present. It should contain both the independent and dependent variable. The first column usually contains the values of the independent variable, and the second column contains the values of the dependent variable. Each column should have a heading that names the values and the unit of measurement that was used. If quantitative data (numbers) are used, then it should be ordered from smallest value to the largest value.

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 (Figure 2). The shape of the graph gives a hint of how the two variables are related.

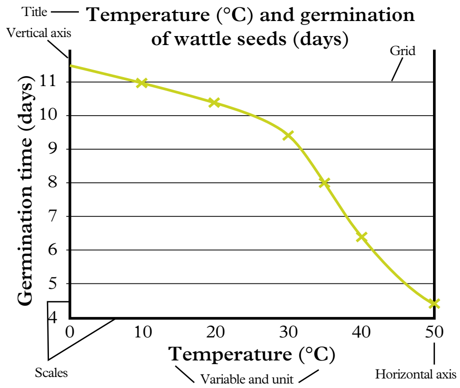


Figure 2 The independent variable (temperature) should be on the horizontal axis and the dependent variable (germination time) should be on the vertical axis.

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

Ordering of variables
The independent variable should be in the first column.

Ordering of data
The data for the independent variable should be organised from the lowest value to the highest.

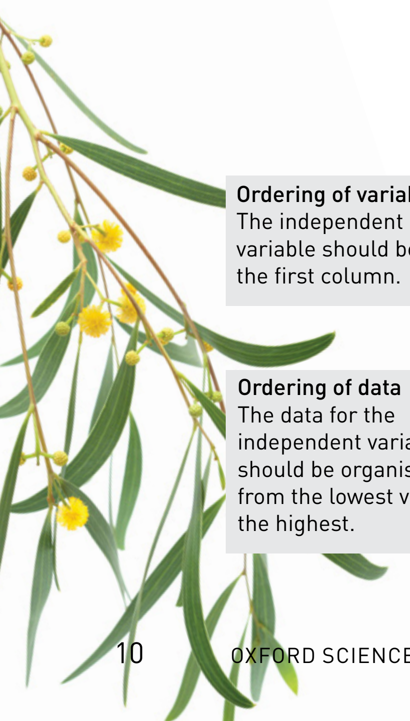
Table 1 Average weight of juvenile koalas by age

Age (weeks)	Weight (kg)
24	0.5
36	1.5
52	2.0

Title for table
The title should contain both the independent variable and the dependent variable.

Column headings
The variable should be identified and the unit of measurement included.

Figure 1 Tables are used to record data.



When the line slopes upwards, this means the dependent variable increases as the independent variable increases. This is called a **directly proportional relationship** (Figure 3).

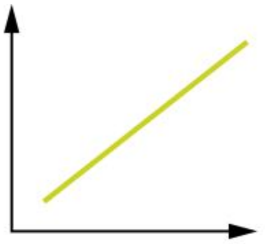


Figure 3 A directly proportional relationship

When the line is horizontal (flat), it means the dependent variable is not affected by the independent variable (Figure 4).

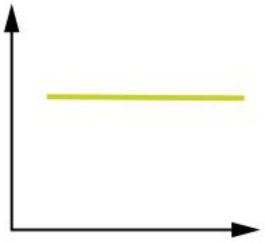


Figure 4 The dependent variable is not affected by the independent variable.

If the line slopes downwards, then the dependent variable decreases as the independent variable increases. This is called an **inversely proportional relationship** (Figure 5).

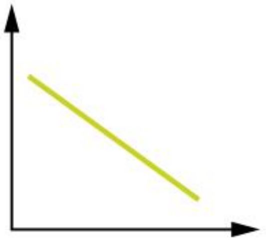


Figure 5 An inversely proportional relationship

Occasionally a graph is curved (Figure 6). 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.

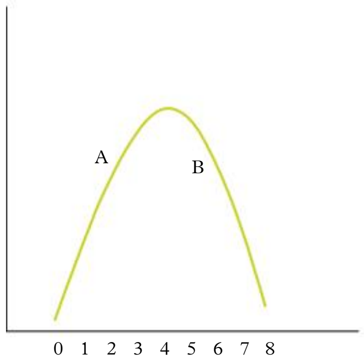


Figure 6 A curved graph is divided into sections.

Sometimes you may have recorded the results for a set of whole numbers. An example of this is in Experiment 1.5 in the Experiments chapter, when you will pull back the elastic and marshmallow 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 7).

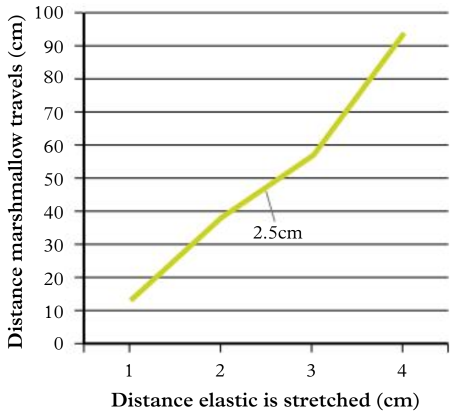


Figure 7 Change in distance travelled by a marshmallow released from an elastic slingshot

1.3 Check your learning

Retrieve

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

2 **Recall** what it means when a graph of the independent and dependent variables is horizontal (flat).

Comprehend

3 **Describe** the relationship between the independent variable and dependent variable shown in Figure 8.

4 A scientist was collecting data on the change in height of a plant over seven days. **Construct** a table that could be used to record this data.

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

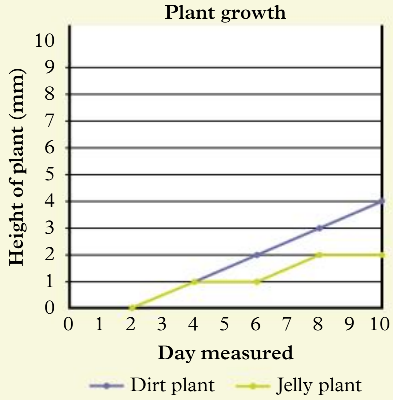


Figure 8 A graph showing plant growth

6 a **Represent** the data in Table 1 as a graph.

b **Identify** the relationship between the variables and **explain** your reasoning.

Table 1 Energy in chocolate bars

Number of chocolate bars	Energy (kilojoules)
3	606
4	808
6	1212
8	1616
10	2020

Quiz me

Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

1.4 Scientists present their data accurately

Learning intentions

By the end of this topic, you will be able to:

- explain outliers in data and how to deal with them
- identify the median in a data set
- calculate the mean and mode of a data set.

Key ideas

- Repeating an experiment helps to identify errors.
- Outliers are values that are very different from the main group of data.
- Outliers can affect the mean (average) of the overall results.
- The median (middle number of data when placed in increasing order) or the mode (most common result) is less affected by outliers.

Comparing results

It can sometimes be difficult for a scientist to know if their results are accurate, especially if they have only tried an experiment one or two times. For example, a botanist (a scientist who studies plants) plans an experiment to see if the amount of water given to a plant affects its growth. If only one plant is watered every day and dies, the botanist may claim that water killed the plant. They may not be able to see that the plant was infected with a fungus, and this was the reason that it died.

If the botanist tried watering 50 different plants every day and half of them died, they may still claim that some plants do not like water. While there are some plants that do not grow well with too much water, it would be difficult to claim this in an experiment if all the plants were different. A well-designed plant experiment should use many identical plants.

Sometimes this is difficult to do, so scientists will compare their methods and results to that of other scientists. If the methods are the same (consistent), all of the variables controlled and the measurements are accurate, then the data can be combined and analysed.

Outliers

outlier
a data value that is outside the range of all the other results

Occasionally the data that scientists collect contains a value that is far away from the main group of data. These values are called **outliers** and may be due to inaccurate measurements or experimental errors.

Consider the data in Table 1, which records the height of seedlings after three weeks of growth.

Table 1 Seedling growth after three weeks

Seedling number	Height (cm)
1	3.6
2	4.0
3	4.1
4	4.0
5	0.1
6	3.5
7	4.3

All seedlings except seedling 5 grew between 3.5 and 4.3 cm. The height of seedling 5 after three weeks is an outlier. The average (or mean) growth of the seedlings (including seedling 5) is 3.4 cm, which is below the growth of any of the seedlings other than seedling 5. This shows how one outlier can present a distorted result of the seedling growth.

If the average is determined without using the height of seedling 5, the average becomes 3.9 cm. This is a closer representation of the actual growth. However, is it fair to discard any results that we don't like?

An outlier is only excluded if an explanation is given as to how the results have been modified and the reason for doing so. For example, the discussion might include the statement that 'Seedling 5 was excluded from the analysis because a fungal infection affected its growth.'

Worked example 1.4: Calculating the mean

Determine the average (mean) of the seedling heights shown in Table 1.

Solution

$$\text{Average seedling height} = \frac{\text{sum of all seedling heights}}{\text{number of seedlings}}$$

$$= \frac{3.6 + 4.0 + 4.1 + 4.0 + 0.1 + 3.5 + 4.3}{7}$$

$$= \frac{23.6}{7}$$

$$= 3.371$$

As the seedling heights had two significant figures and one decimal place, the final answer must have two significant figures and one decimal place. The average seedling height is 3.4 cm (3.371 is closer to 3.4 than to 3.3).

Figure 1 How should you calculate the average growth of seedlings?

Median

The median is the middle value of the data after all the numbers have been placed in increasing order. For the previous data, this means:

$$0.1,\ 3.5,\ 3.6,\ \underset{\substack{\uparrow \\ \text{median}}}{4.0},\ 4.0,\ 4.1,\ 4.3$$

The median amount the seedlings grew was 4.0 cm. If the outlier is removed, the median growth is still 4.0 cm. The median value of the data is not affected as much by outliers as the mean/average is.

Mode

The mode is the most common number in the set of data. In our set of data, the number 4.0 occurs twice (seedlings 2 and 4).

This means the mode, or most common amount the seedlings grew, was 4.0 cm. If the outlier was removed, the mode of the seedling growth would still be 4.0 cm. An outlier does not affect the mode value.

1.4 Check your learning

Retrieve

1 **Recall** why it is best to present your data in table form.

2 **Define** the following terms.
  - a outlier
  - b median
  - c mean
  - d mode

Comprehend

3 **Explain** why scientists often repeat experiments and then take an average.

4 **Describe** when an outlier should be included in the results.

Table 2 Number of ice creams sold in comparison to the daily temperature

Temperature (°C)	Ice creams sold
14.2	215
16.4	325
11.9	185
15.2	332
18.5	406
22.1	522
19.4	112
25.1	614
23.4	544
18.1	421
22.6	445
17.2	408

Analyse

5 Draw an appropriate graph for the data in Table 2.
  - a **Identify** the outlier in the data.
  - b **Calculate** the mean number of ice creams sold each day.
  - c **Calculate** the median temperature over the 12 days.

Quiz me

Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

1.5 Scientists keep a logbook

Learning intentions

By the end of this topic, you will be able to:

- create and use an experimental logbook.

Key ideas

- An experimental 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 Moreton Bay 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 for creating and using a logbook.

1 Use a bound notebook (Figure 2) 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 be 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 2 shows a sample logbook entry. Start a logbook to record your observations and the data you collect in Experiment 1.5 in the Experiments chapter.

Figure 1 Logbooks contain important data and observations from experiments.

1.5 Check your learning

Retrieve

1 **State** the purpose of an experimental logbook.

2 A student made a mistake and ripped that page out of their logbook. **Recall** why this would be the wrong thing to do.

Comprehend

3 **Explain** why an electronic logbook should be backed up regularly.

Analyse

4 **Infer** why it is important to make sure the writing in your logbook is legible (able to be read).

5 **Infer** one reason why it is important to include the date of the experiment in the logbook.

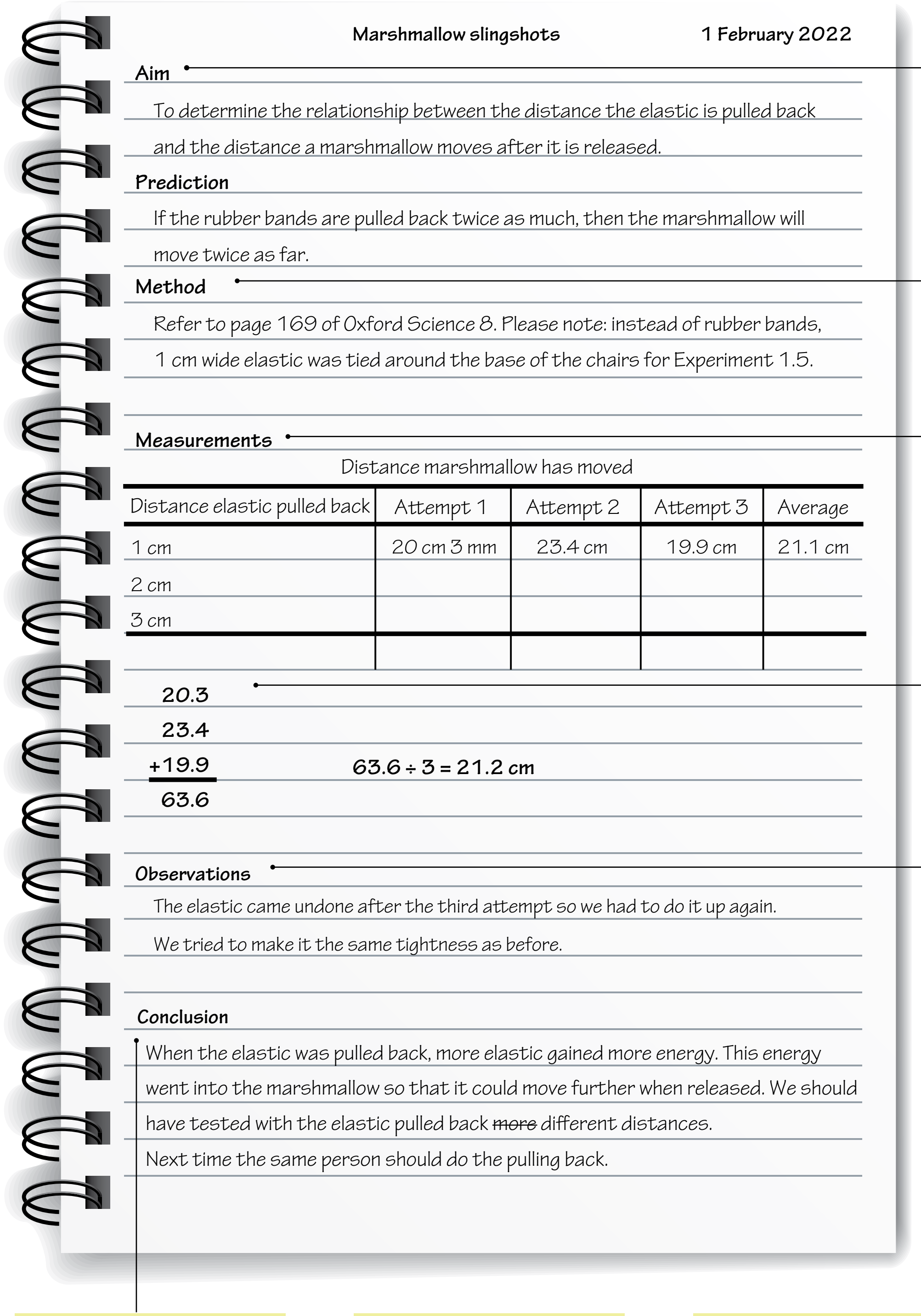
6 **Infer** why you should reflect on each experiment before starting the next experiment.

Quiz me

Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

EXPERIMENT

1.5: Marshmallow slingshots
Go to page **169**.



Marshmallow slingshots **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 169 of Oxford Science 8. Please note: instead of rubber bands, 1 cm wide elastic was tied around the base of the chairs for Experiment 1.5.

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				

$$\begin{array}{r} 20.3 \\ 23.4 \\ +19.9 \\ \hline 63.6 \end{array} \qquad 63.6 \div 3 = 21.2\text{ cm}$$

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.

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.

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.

Figure 2 A sample logbook entry

1.6 Cognitive verbs identify the tasks in a question

Learning intentions

By the end of this topic, you will be able to:

- recognise the cognitive verb in a question
- understand the different tasks involved for different cognitive verbs.

Key ideas

- Cognitive verbs are 'doing words' that ask you to perform a specific task.
- Cognitive verbs can be grouped into categories based on how much thinking and understanding is required to perform the task.

cognitive verb
a doing word that requires you to perform a specific thinking task

Cognitive verbs

A **cognitive verb** is a verb or 'doing word' that requires thinking to perform a set task. For example, the word 'describe' is a cognitive verb because it requires you to remember what you know about something and talk about its features. Cognitive verbs are commonly used in questions which means you will encounter a variety of cognitive verbs in school as you learn new information.

Common cognitive verbs and the task/s associated with them are given in Table 1. Understanding these cognitive verbs and the tasks behind them can help you figure out how to best answer a question (Figure 1).

Figure 1 Familiarising yourself with different cognitive verbs can help you answer questions and improve your learning.

Figure 2 Two healthy fruits

Some cognitive verbs require more thinking and understanding than others. For example, if you were asked to *name* the two fruits in Figure 2, you might instantly remember 'apple' and 'orange' and could write the names down without much trouble. However, if you were asked to *compare* the two fruits, you would need to consider the two fruits and identify at least one similarity and one difference between them. In this sense, 'compare' requires a deeper level of thinking than 'name'.

Table 1 shows how the type/s of thought processes behind the task can be used to categorise cognitive verbs. Throughout this book you will notice that you are usually tasked with 'retrieve' type questions before you are asked 'apply' type questions. This is because working in order from retrieve to comprehend to analyse and finally apply helps your learning process.

Table 1 Common cognitive verbs and their tasks

Cognitive verb	Task	Category
Define	give the meaning of a word	**Retrieve** – Recall information from permanent memory.
Identify	recognise and state a distinguishing factor or feature	
Name	provide the correct term or noun	
Recall	present remembered ideas, facts or experiences	
Use	operate or put into effect	
Select	pick out	
Describe	give an account of a situation, event, pattern or process, or of the characteristics or features of something	**Comprehend** – Activate and transfer knowledge from your permanent memory to your working memory.
Explain	make an idea or situation plain or clear by describing it in more detail or revealing relevant facts	
Summarise	give a brief statement of a general theme or major point/s; present ideas and information in fewer words and in sequence	
Calculate	determine or find (e.g. a number, answer) by using mathematical processes	**Analyse** – Use your reasoning to go beyond what was directly taught.
Categorise	place in or assign to a particular class or group	
Classify	arrange, distribute or order in classes or categories according to shared qualities or characteristics	
Compare	display recognition of similarities and differences and recognise the significance of these similarities and differences	
Contrast	give an account of the differences between two or more items or situations	
Distinguish	recognise as distinct or different; note points of difference between	
Interpret	use knowledge and understanding to recognise trends and draw conclusions from given information	
Create	reorganise or put elements together into a new pattern or structure	**Apply** – Use your knowledge in specific situations.
Discuss	examine by argument; sift the considerations for and against; talk or write about a topic	
Evaluate	examine and determine the merit, value or significance of something	
Elaborate	investigate, inspect or scrutinise	
Justify	give reasons or evidence to support an answer, response or conclusion	
Predict	give an expected result of an upcoming action or event	

1.6 Check your learning

Retrieve

1 **Define** the term ‘cognitive verb’.

2 **Identify** the cognitive verb that requires you to give reasons in support of an answer or conclusion.

Comprehend

3 **Describe** what is required to correctly answer:

- a a ‘summarise’ question
- b a ‘classify’ question
- c a ‘predict’ question.

Analyse

4 **Distinguish** between ‘compare’ and ‘contrast’.

Apply

5 A student was asked to ‘compare’ the apple and orange in Figure 2. Their response was ‘Both the apple and orange are round in shape’. **Discuss** whether the student has correctly answered the question.

Quiz me

Complete the Quiz me to check how well you’ve mastered the learning intentions and to be assigned a worksheet at your level.

CHAPTER 1 REVIEW

SCIENCE TOOLKIT

Retrieve

1 **Identify** which of the following is a hypothesis.
- A Plants need water.
- B A plant needs to be watered every day.
- C If a plant was not watered, then it would die.
- D If a plant was not watered then it would die because plants need water to grow.

2 Figure 1 shows the distance a marshmallow travelled when it was released from a slingshot stretched to various lengths. **Recognise** the relationship between the variables shown on the graph.
- A directly proportional
- B inversely proportional
- C having no direct relationship
- D a negative relationship

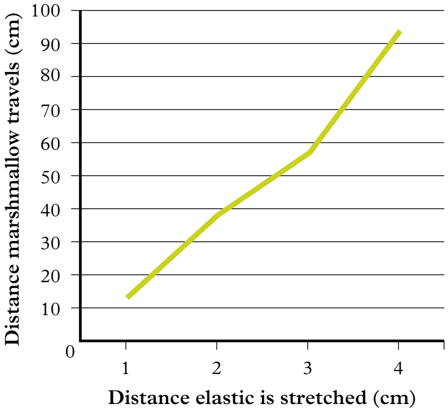


Figure 1 Distance a marshmallow travels according to distance elastic is stretched

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

4 **Define** the following terms.
- a parallax error
- b positive correlation
- c dependent variable
- d outlier

5 **State** the SI unit for the following measurements.
- a time
- b mass
- c length
- d volume

6 **State** the meaning of and write the symbol for the prefix for each of the following units of measurement.
- a teralitre
- b megalitre
- c microlitre
- d nanolitre

7 **Name** the four features that should be present on all graphs.

8 **Recall** the information that should be included in an experimental logbook.

Comprehend

9 A student is planting out a new garden bed. They research how to care for their plants and learn that some people water their plants with orange juice as well as with water. The student wants to try this but doesn't know how often to use orange juice. The student starts an investigation.
- a **Represent** the student's science question, noted below, as a hypothesis.

  'What if a seedling is watered with orange juice once per day?'
- b **Identify** the independent and dependent variables in the hypothesis you have written.

10 **Explain** why it is best to present your data in table form.

11 **Represent** in a graph the data in Table 1 which shows how much Enza has grown in her first 8 years.

Table 1 Enza's growth from age 1 year to 8 years

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

12 **Summarise** why two scientists might compare their experimental results.

13 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 three flowers on the rose bush. **Explain** why the scientist's observations of a single rose bush should not be extended to all rose bushes.

14 **Describe** the type of information that may be included in your logbook.

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

16 A student conducted an experiment and did not keep a logbook. The student's teacher asked the student to prepare a formal report about the experiment for their class assessment. **Explain** the problems the student will have when writing the report.

Analyse

17 Two students used two different balances to weigh some rock samples. Their results are in Table 2.

Table 2 Weight of rock samples

Rock sample number	Weight (g)
1	28.03
2	35.24
3	37.639
4	30.426

Calculate the average weight of the rocks. Give your answer to the appropriate number of significant figures.

18 **Calculate** the mean, median and mode of the following set of data.

15, 13, 18, 16, 14, 17, 12, 13, 19

19 **Contrast** the independent variable and the dependent variable.

20 **Differentiate** between a directly proportional relationship and an inversely proportional relationship.

21 **Contrast** causation and correlation.

22 **Compare** parallax error and zero error.

23 **Identify** the number of significant figures in each of the following measurements.

- **a** 65.301 g
- **b** 0.006420 kg
- **c** 40 L

24 A student recorded the results of an experiment in Table 3. **Identify** any errors in the table set up.

Table 3

Distance marshmallow travels	Distance elastic stretched
93	4
55	3
38	2
12	1

25 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.

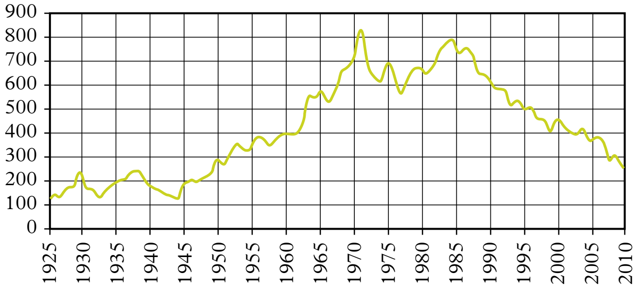


Figure 2 A graph showing the number of road deaths from 1925 to 2010

Apply

Creative and critical thinking

26 Scientists often need to find new and creative ways to present the results of their experiments. **Propose** two ways a scientist could publish information to the public. For each option, describe the audience they are trying to reach.

27 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. **Investigate** and **discuss** one advantage of the peer review process.

28 **Discuss** why you think working in order from 'retrieve' to 'comprehend' to 'analyse' and finally to 'apply' type questions is beneficial for your learning.

Social and ethical thinking

29 When writing a report for a scientific journal, scientists will often mention the results of experiments from other scientists. If this work is a result of First Nations peoples' cultural practices, then the scientist is encouraged to use the CARE principles. Select one of the principles and **discuss** why it is important.

Collective benefit: using this data should provide benefit to First Nations peoples.

Authority to control: First Nations peoples should have the right to control their data.

Responsibility: those using the data have the responsibility to engage respectfully with First Nations communities.

Ethics: the ethics of First Nations peoples should be used to minimise harm, maximise benefits and allow for future use.

Research

30 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.

Figure 3 Rolls of packing tape

» Matilda effect

Historical science books are dominated by the discoveries of male scientists. The research of female scientists was often ignored or accredited to their male colleges. This 'Matilda effect' was first described by suffragist Matilda Joslyn Gage in 1870.

- Investigate the work of one of the following scientists: Jeanne Baret (1740–1807); Marian Diamond (1826–2017); Nettie Stevens (1861–1912); Rosalind Franklin (1920–1958).
- Describe the work that they did, what they discovered and who received credit for their work.

Figure 4 Matilda Joslyn Gage

» First Nations knowledge

First Nations peoples of Australia have used their experiences to identify plants that can be used for food or medicines. This knowledge has been shared with other Australians, who are investigating producing these plants in commercial (large) quantities for sale.

- Propose who should be recognised for these scientific discoveries.
- Justify your decision by explaining how each group (First Nations peoples or European owners of companies) contributed to the research, production and sale of a product such as kakadu plum foods and beauty products. Propose how the contributors could be recognised.

Figure 5 *Terminandia ferdinandiana* or kakadu plum

Chapter checklist

Now that you have completed this chapter, reflect on your ability to do the following.

	I can do this.	I cannot do this yet.
• Describe a relationship between two sets of data. • Develop investigable questions, reasoned predictions and hypotheses.	☐	☐ Go back to Topic 1.1 'Scientists ask questions'. Page 4
• Explain the importance of minimising experimental errors. • Identify experimental errors and numbers of significant figures. • Use rounding off techniques, the SI system and derived units.	☐	☐ Go back to Topic 1.2 'Scientists must be aware of experimental errors'. Page 6
• Interpret data in tables and on line graphs. • Identify and describe directly proportional and inversely proportional relationships on line graphs.	☐	☐ Go back to Topic 1.3 'Tables and graphs are used to present scientific data'. Page 10
• Explain outliers in data and how to deal with them. • Identify the median in a data set. • Calculate the mean and mode of a data set.	☐	☐ Go back to Topic 1.4 'Scientists present their data accurately'. Page 12
• Create and use an experimental logbook.	☐	☐ Go back to Topic 1.5 'Scientists keep a logbook'. Page 14
• Recognise the cognitive verb in a question. • Understand the different tasks involved for different cognitive verbs.	☐	☐ Go back to Topic 1.6 'Cognitive verbs identify the tasks in a question'. Page 16

Check your Student obook pro for these digital resources and more:

Quizlet

Play a Quizlet game to test your knowledge.

Chapter quiz

Test your understanding of this chapter with the chapter review quiz.

CHAPTER

2

THE ROCK CYCLE

2.1

Rocks have different properties

- Recall the properties of rocks.
- Identify rock samples, including by using a provided dichotomous key.

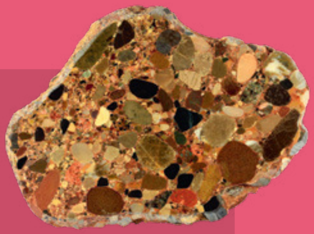
2.2

Igneous rocks develop from magma and lava

- 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 rocks with the way in which they are formed.

2.3

Sedimentary rocks are compacted sediments



- Describe the process of sedimentary rock formation.
- Name several sedimentary rocks.
- Explain the difference between biological and chemical rocks.

2.4

Metamorphic rocks require heat and pressure

- Define metamorphic rock, foliation and index mineral.
- Describe the process of metamorphic rock formation.
- Explain why metamorphic rocks are stronger than the original material.

2.5

The rock cycle causes rocks to be re-formed

- Describe the rock cycle, weathering, erosion, onion-skin weathering and frost shattering.
- Describe the differences between physical, chemical and biological weathering.

2.6

Weathering and erosion can be prevented

- Describe the reasons for soil erosion.
- Describe ways to reduce or prevent soil erosion.

2.7

The age of a rock can be calculated

- Describe two different types of fossils.
- Use fossil evidence to predict how and when rock was formed.

2.8

Science as a human endeavour: The locating and extraction of minerals relies on scientists

- Describe the processes of geophysical and geochemical testing.
- Evaluate the benefits and costs of mining.

What if?

Rocks

What you need:

Selection of different rocks for each group

What to do:

1 Divide the 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

Learning intentions

By the end of this topic, you will be able to:

- recall the properties of rocks
- identify rock samples, including by using a provided dichotomous key.

Key ideas

- 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.

Similarly, First Nations peoples use their knowledge of the properties of different rocks to make tools. For example, abrasive rock, such as sandstone, is used to grind seeds and other plant material.

You can identify rocks first by how they look. Coal is black or dark brown. Pumice and scoria are covered with holes. Each rock is made up of tiny grains or crystals called minerals. These minerals have unique properties that can determine the properties of the rock. Granite is made up of large crystals of the minerals quartz, mica and feldspar. This can make it very hard. Other rocks can break off in layers of minerals. Some, like conglomerates, are made up of individual stones cemented together.

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

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

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.

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	Medium	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

SKILLS LAB
2.1: Identifying rocks
Go to page **170**.

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.

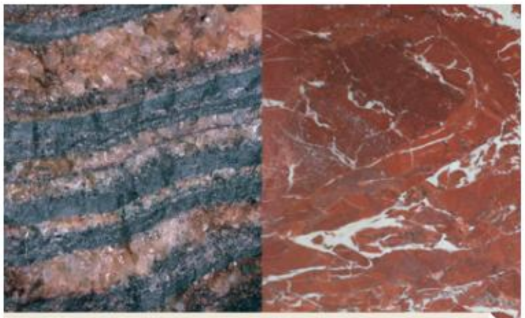


Figure 3 Colour is a property that depends on the chemicals in the rocks. For example, some red rocks contain a lot of iron, which has reacted with oxygen in the air ('rusted') to form red iron oxide. Other red rocks don't contain iron, so a rock cannot be identified solely by its colour.

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

Retrieve

1 **Recall** the branch of science that is the study of rocks.

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

Comprehend

3 **Explain** why properties other than colour should be used to identify a rock.

Analyse

4 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.

Apply

5 **Investigate** different uses for three rock types of your choice.

6 **Determine** whether pumice would 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).

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

2.2 Igneous rocks develop from magma and lava

Learning intentions

By the end of this topic, you will be able to:

- 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 rocks with the way in which they are formed.

Key ideas

- 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
semi-liquid 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 (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 (Figure 2). 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.

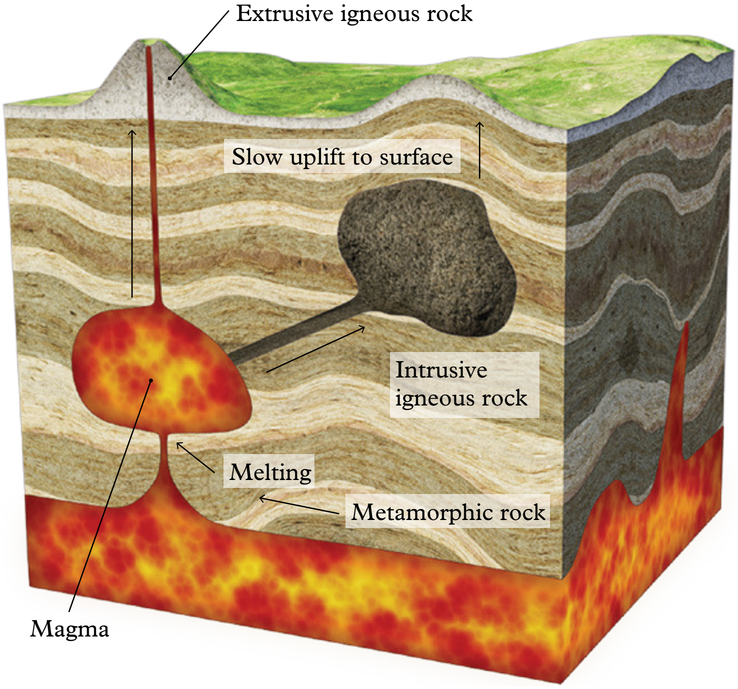


Figure 1 Igneous rocks are formed from volcanic magma.

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.

EXPERIMENT

2.2: What affects crystal size?
Go to page **171**.

Figure 2 Granite is an intrusive igneous rock.

It has so many holes that it is extremely light and can float on water (Figure 3). Pumice stones are used to scour hard skin from feet, and powdered pumice is found in some abrasive cleaning products.

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 (Figure 4a). First Nations peoples also use the hard basalt with strong tensile strength in the production of stone axes. Basalt can look different depending on the type of volcanic eruption that produced it and how quickly it cooled.

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

Scoria is a type of basalt that is full of bubble holes (Figure 4b). 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 (Figure 4c). It is formed almost instantly when lava cools and forms no crystals. Obsidian is used to make blades for surgery scalpels; the resulting blades are much sharper than those made from steel.

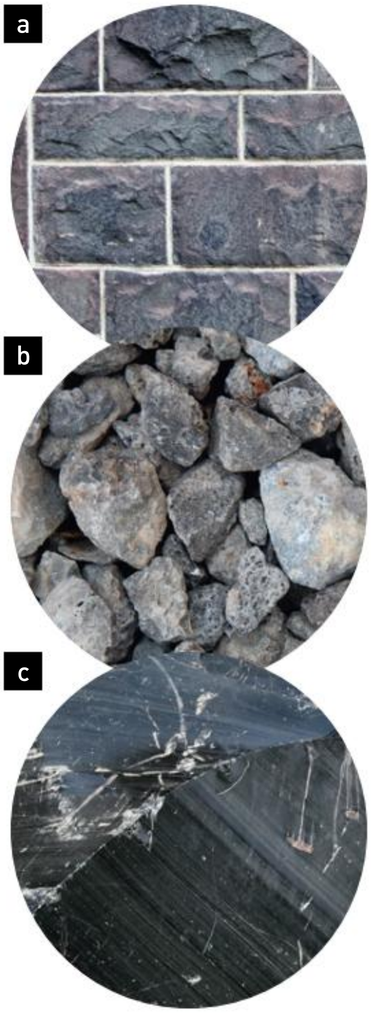


Figure 4 Basalt comes in different forms: **a** bluestone, **b** scoria and **c** obsidian.

2.2 Check your learning

Retrieve

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

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

3 **Recall** an igneous rock that would float on water.

Comprehend

4 **Describe** how igneous rocks form.

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

Analyse

6 a **Contrast** (the differences between) the properties of intrusive and extrusive igneous rocks.
  b **Consider** the ways humans use these rocks and how their properties are important for their uses.

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

2.3

Sedimentary rocks are compacted sediments

Learning intentions

By the end of this topic, you will be able to:

- describe the process of sedimentary rock formation
- name several sedimentary rocks
- explain the difference between biological and chemical rocks.

Key ideas

- Sedimentary rocks are formed from compacted particles or sediment.
- Stalactites and stalagmites are forms of sedimentary rock.

Sedimentary rocks are formed when loose particles are pressed together (compacted) by the weight of the overlying sediments (Figure 1). 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.

Video 2.3
Sedimentary rocks

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

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 (Figure 2). Sandstone is made up of sand deposited in environments such as deserts and beaches (Figure 3). Conglomerate is a mixture of all sizes of rocks that have become cemented together (Figure 4).

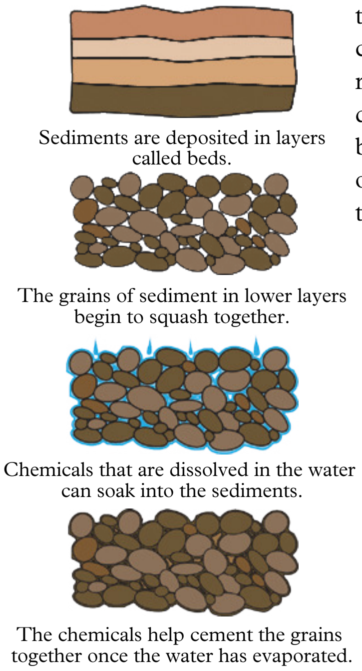


Figure 1 The formation of sedimentary rocks

Figure 2 Shale (or mudstone) is the most common sedimentary rock. Shale is a fine-grained sedimentary rock made up of clay minerals or mud.

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

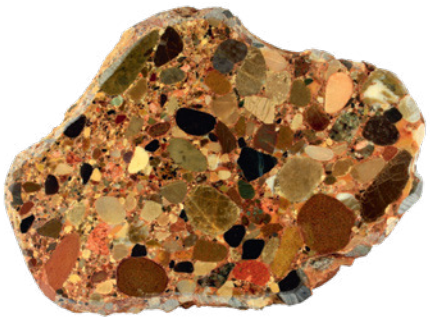


Figure 4 Conglomerate rocks have grains of different sizes.

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.

EXPERIMENT

2.3: Making sedimentary rocks
Go to page **172**.

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') (Figure 5). 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 5 Stalagmites and stalactites form in limestone caves.

Ochre

Ochre is one of the sedimentary rocks most valued by First Nations peoples in Australia. It is valued for its high shine that generates a shimmering effect in the light of a fire. It is used in body paint, rock paint and on artwork. There are six colours of ochre, from yellow to deep orange or brown. First Nations peoples have mined and traded sedimentary ochre for thousands of years. Wilgie Mia in Western Australia is 20 metres underground and is the world's oldest continuous mining operation (Figure 6). This 27 000–40 000-year-old mine used pole scaffolding to prevent the mine from collapsing on the miners while thousands of rocks were removed to reach the ochre.

Figure 6 Wilgie Mia ochre mine

2.3 Check your learning

Retrieve

1 **Recall** how sedimentary rocks form.

2 **Name** three different sedimentary rocks.

3 **Recall** how stalactites and stalagmites form.

Comprehend

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

Analyse

5 **Compare** (the similarities and differences between) the formation of biological and chemical sedimentary rocks.

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

Apply

7 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).

Quiz me

Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

2.4

Metamorphic rocks require heat and pressure

Learning intentions

By the end of this topic, you will be able to:

- define metamorphic rock, foliation and index mineral
- describe the process of metamorphic rock formation
- explain why metamorphic rocks are stronger than the original material.

Key ideas

- 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 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. For example, limestone changes to marble (Figure 1).

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** (Figure 2).

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 in the rock – 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.

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

Figure 2 Foliation occurs when rock is subjected to uneven pressure.

Figure 1 The Taj Mahal in India is made of marble, the metamorphosed form of limestone. With its dense composition and beautiful patterns, marble is a popular material for sculptures and kitchen benchtops.

EXPERIMENT

2.4: Making a metamorphic rock
Go to page **173**.

Figure 3 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.

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 (Figure 3). This can affect how metamorphic rocks are used.

Metamorphic rocks are stronger than the original material because the particles have been fused together under great pressure or heat. This strength made rocks such as quartzite useful to First Nations peoples for producing grindstones and millstones (Figure 4). The rough surfaces of the stones made it easier to produce flour from different seeds. The Bama people of northern Queensland, however, cut ridges in smooth slate so that the rough surface could be used to grind toxic cycad kernels. Grinding the kernels with water releases the toxins and makes the kernels safer to eat.

The Bama people knew that slate, which absorbs little water, would not absorb the toxins from the ground kernels, making the tools safe to use over and again.

Figure 4 A quartzite grindstone used by First Nations peoples

2.4 Check your learning

Retrieve

1 **State** where metamorphic rocks are formed.

Comprehend

2 **Describe** how metamorphic rocks are formed.

3 **Describe** a foliated rock.

4 **Explain** why quartzite is useful for a grindstone.

Apply

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 a **Identify** which type of rock is stronger: sandstone or marble.

b **Justify** your answer (by explaining how each rock is formed, linking this to its properties and deciding which is stronger).

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

2.5 The rock cycle causes rocks to be re-formed

Learning intentions

By the end of this topic, you will be able to:

- describe the rock cycle, weathering, erosion, onion-skin weathering and frost shattering
- describe the differences between physical, chemical and biological weathering.

Key ideas

- 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 2.5
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 (Figure 1). Each part of the rock cycle can take up to 20 million years.

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** (Figure 2a).

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 2c).

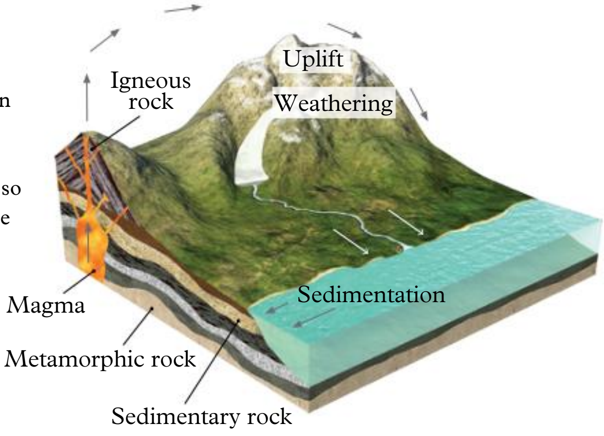


Figure 1 The rock cycle

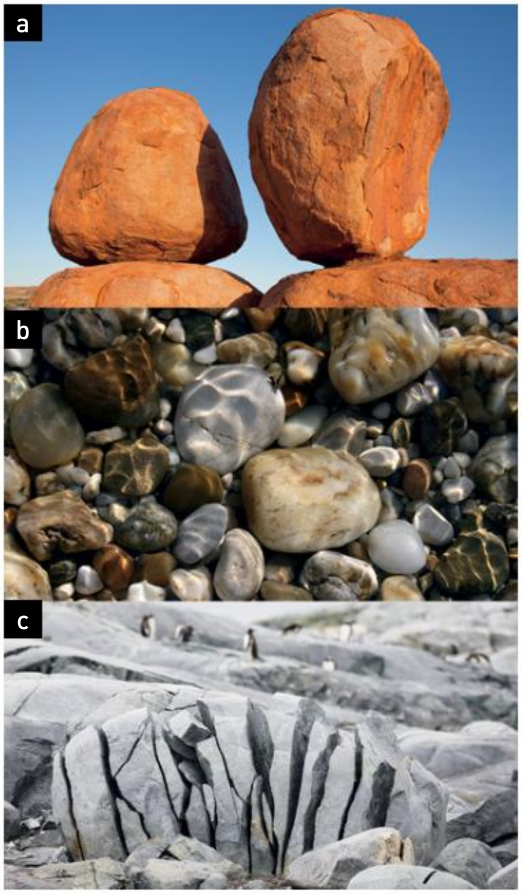


Figure 2 Physical weathering can include **a** onion-skin weathering, **b** wearing away by water (abrasion) and **c** frost shattering.

SKILLS LAB

2.5: Modelling the rock cycle
Go to page **174**.

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 (Figure 3).

Biological weathering

Biological weathering can start with a seed falling into a crack in the rock. Soil and water in the rock encourage the seed to grow. As the roots grow, they push on the cracks in the rock, eventually causing the rock to break (Figure 4).

Deposition

Over time and during the process of weathering, large rocks are broken down into smaller rocks, which are broken down into sediment. The sediment is eroded and carried by wind and water to an area where it accumulates in layers. Over time, many different layers of sediment from the different forms of weathering are built on top of each other. This process is called **deposition**. 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 from the heavy top layers. Over time, the layers sink deeper, putting even more pressure on the deep layers. This can cause the rocks to heat up. 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, the rock is uplifted and exposed to wind and water. The cycle continues.

Figure 3 Chemical weathering can be caused by acid rain.

deposition
the process whereby sediment from different forms of weathering accumulates in layers

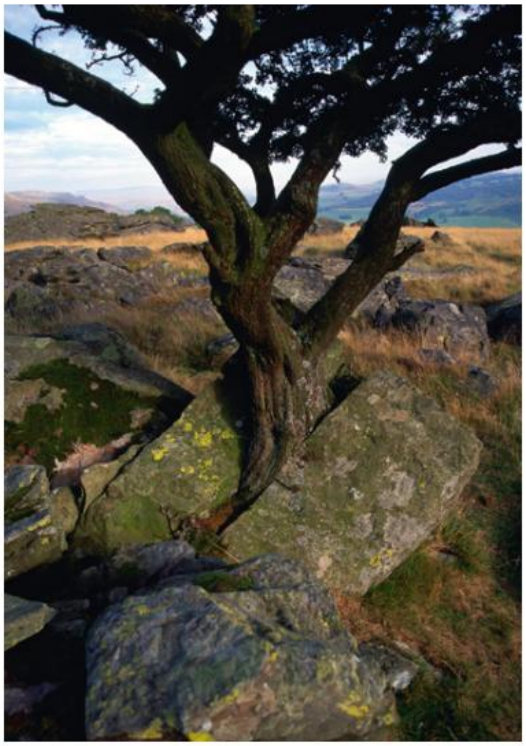


Figure 4 Biological weathering can be caused by plant roots.

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

2.5 Check your learning

Comprehend

1 **Describe** how tors are formed.

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

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

Analyse

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

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

Apply

6 **Create** a story about 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. Remember to include the length of time that each step of the process takes.

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

2.6

Weathering and erosion can be prevented

Learning intentions

By the end of this topic, you will be able to:

- describe the reasons for soil erosion
- describe ways to reduce or prevent soil erosion.

Key ideas

- 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 (Figure 2). 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 landslides (Figure 3). 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.

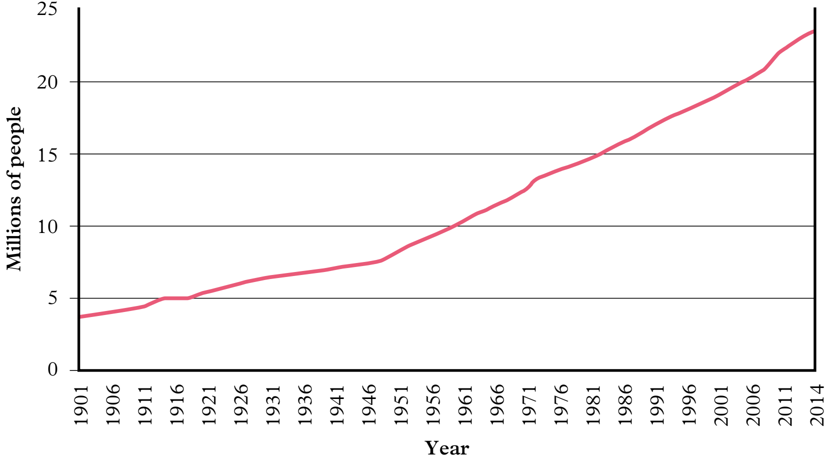


Figure 3 Soil erosion can lead to landslides that affect footpaths, houses and roads, endangering people's lives.

CHALLENGE

2.6: Preventing soil erosion
Go to page **175**.

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 human-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.

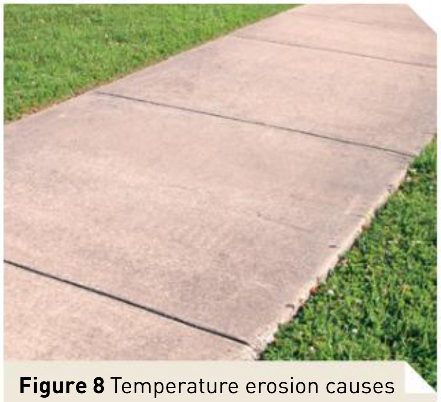


Figure 8 Temperature erosion causes materials such as concrete to crack. Footpaths have grooves in them to allow for their expansion during hot weather.

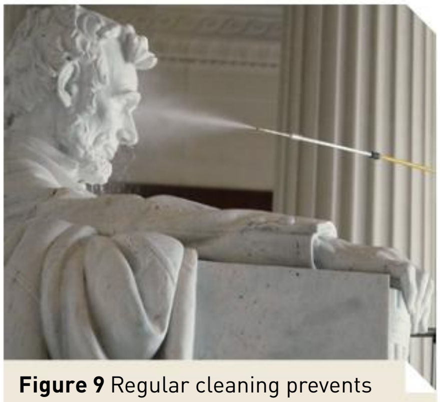


Figure 9 Regular cleaning prevents the build-up of moss and pollution that might contribute to biological or chemical erosion.

2.6 Check your learning

Retrieve

1 **Recall** why a groyne might be used on a beach.

2 **State** what a soil engineer does.

Comprehend

3 **Explain** how an engineer could prevent water from eroding soil.

Analyse

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

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

Apply

6 Find an area near your school that has been affected by erosion. **Propose** a way to prevent further erosion.

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

2.7

The age of a rock can be calculated

Learning intentions

By the end of this topic, you will be able to:

- describe two different types of fossils
- use fossil evidence to predict how and when rock was formed.

Key ideas

- Fossils can tell how and when a rock was made.
- Fossils can be the remains of an organism.
- Trace fossils are rock versions of prints of feet or leaves.
- Opalised fossils are replicas of a fossil made of opal.

Over 95 million years ago Australia was populated by megafauna. These large animals included a wombat ancestor the size of a rhinoceros (*Diprotodon optatum*) (Figure 1), and a giant monitor lizard, *Varanus priscus*, that was up to 7 metres long (Figure 2).

Figure 1 *Diprotodon optatum* is the largest marsupial that is known to have existed.

Figure 2 *Varanus priscus* is an extinct giant monitor lizard.

We know that these animals existed because of the fossils found at Lightning Ridge in New South Wales and Coober Pedy in South Australia.

What are fossils?

Fossils are the remains or traces of organisms that are now extinct. A **trace fossil** can include footprints in the mud that become permanent when the sedimentary mud becomes hardened into sedimentary rock. This process can also occur when leaves fall to the ground and leave an imprint or mark in the dirt.

Fossilisation occurs when the footprint or imprint is covered by sediment (Figure 3). This prevents the weathering of the marks. Over time, more layers of sediment are deposited, pushing down on the dry imprinted mud. The pressure allows the sediment to form sedimentary rock.

trace fossil	traces of an organism that existed in the past
fossilisation	the process of an organism becoming a fossil

Fossils are only found in sedimentary rock. If sedimentary rock is exposed to too much pressure or heat, then the rock will undergo physical and chemical changes and become metamorphic rock. These changes will usually destroy the fossil. If the sedimentary rock is melted into magma and cooled into igneous rock, the fossils will also be destroyed.

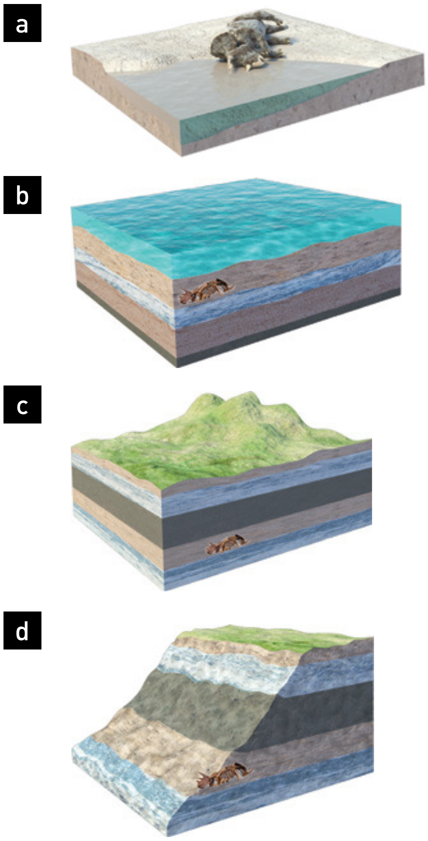


Figure 3 Formation of a fossil **a** and **b** If an organism dies near water, it has a greater chance of being buried in sedimentary sand. This protects the body from being eaten. **c** Over millions of years more sediment is deposited, replacing the remains so they are transformed into sedimentary rock. **d** Uplift, weathering and erosion may cause the fossil to be exposed.

EXPERIMENT

2.7: Making a fossil
Go to page **176**.

Opalised fossils

When some Australian megafauna died, their bodies became covered in sediment such as sand or weathered rocks. This prevented other animals from eating them, or bacteria and fungi from decomposing the body. Sometimes the soft parts of the body would decompose, leaving just the bones to be covered. The bones take longer to break down. If the sediment hardened before the bones decomposed, then a cavity or hole in the shape of the bone would form. Over millions of years, this cavity would become filled with a type of silica, a mineral, that forms opal. This opalised fossil is a copy of the original bones that were buried. Eventually the sedimentary rock may be uplifted and the surrounding rock weathered and eroded, allowing the fossil to be seen.

Predicting the age of a rock

Knowing how long ago a megafauna such as *Zygomaturus trilobus* lived allows us to work out when a sedimentary rock was made. *Zygomaturus trilobus* was another large wombat-like marsupial the size of a large bull (Figure 4). Through a special form of dating that uses the amount of radioactive material in the fossil, it was worked out that the animal died about 33 000 years ago. This means that the sedimentary rock surrounding the fossil was 33 000 years old. The rock that is above the fossil is less than 33 000 years old, and the rock found deeper under the fossil is more than 33 000 years old (Figure 5).

Who killed the megafauna?

For many years it was thought that the Australian megafauna were killed over 50 000 years ago by First Nations peoples who lived in what is now known as Australia. This is now being questioned as the discovery of the 33 000-year-old *Zygomaturus trilobus* at Willandra Lakes, NSW, suggests that the two species lived in the same area for over 17 000 years. This coexistence suggests that the large wombat ancestors were not hunted out of existence during that time.

Figure 4 *Zygomaturus trilobus* lived 33 000 years ago.

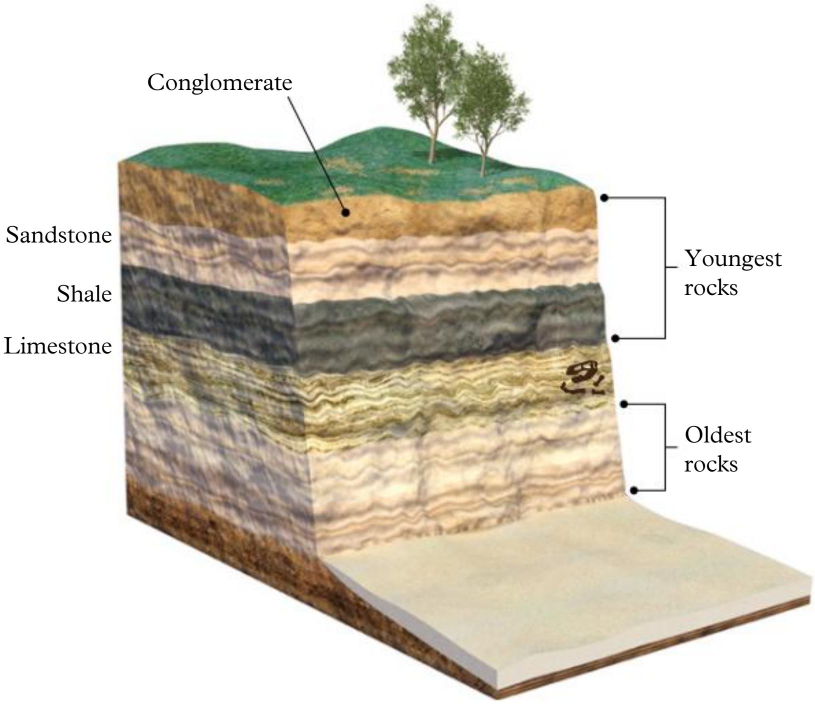


Figure 5 The rock above the fossil must be younger. The rock below the fossil must be older than the fossil.

2.7 Check your learning

Retrieve

1 **Recall** two types of fossils.

2 **Identify** the mineral that is found in opal.

Comprehend

3 **Explain** why fossils are not found in igneous or metamorphic rocks.

4 **Describe** how fossilised opals are formed.

5 **Explain** why First Nations peoples are no longer thought to have hunted megafauna to extinction in Australia.

Apply

6 **Determine** how old the rock above a 50 000-year-old fossil would be.

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

//SCIENCE AS
A HUMAN ENDEAVOUR//

2.8

The locating and extraction of minerals relies on scientists

Learning intentions

By the end of this topic, you will be able to:

- describe the processes of geophysical and geochemical testing
- evaluate the benefits and costs of mining.

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.

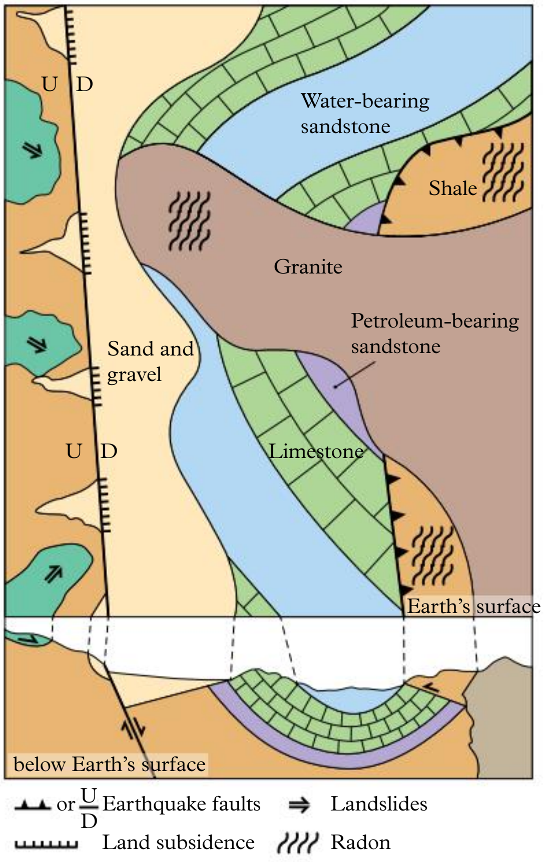


Figure 1 Geological maps allow geologists to determine the location of mineral resources that could be extracted.

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 (Figure 1).

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), vulcanology (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.

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

EXPERIMENT
2.8A: Copper treasure hunt
Go to page **177**.

EXPERIMENT
2.8B: What if a muffin were mined in different ways?
Go to page **178**.

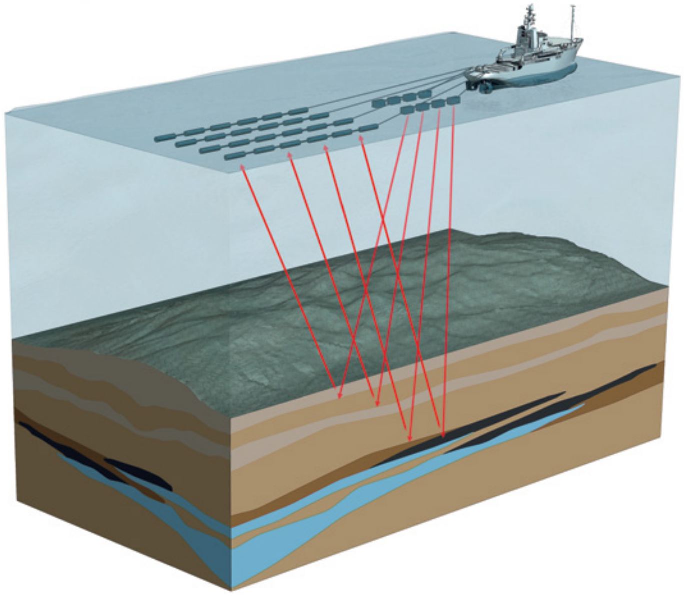


Figure 2 Seismic refraction method

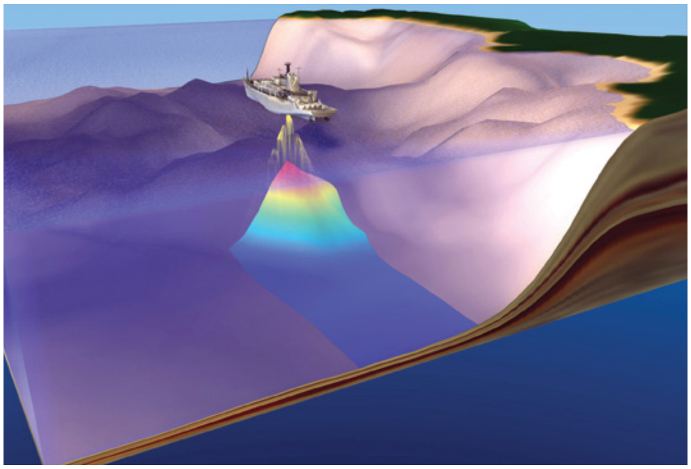


Figure 3 Oceanography boat

Oceanography boats will often carry out geophysical surveys to locate geological structures on the ocean floor (Figures 2 and 3).

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** (Figure 4).

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 (Figure 5 on page 40). 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 (Figure 6 on page 40).

magnetometer
a device that detects the difference in a 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

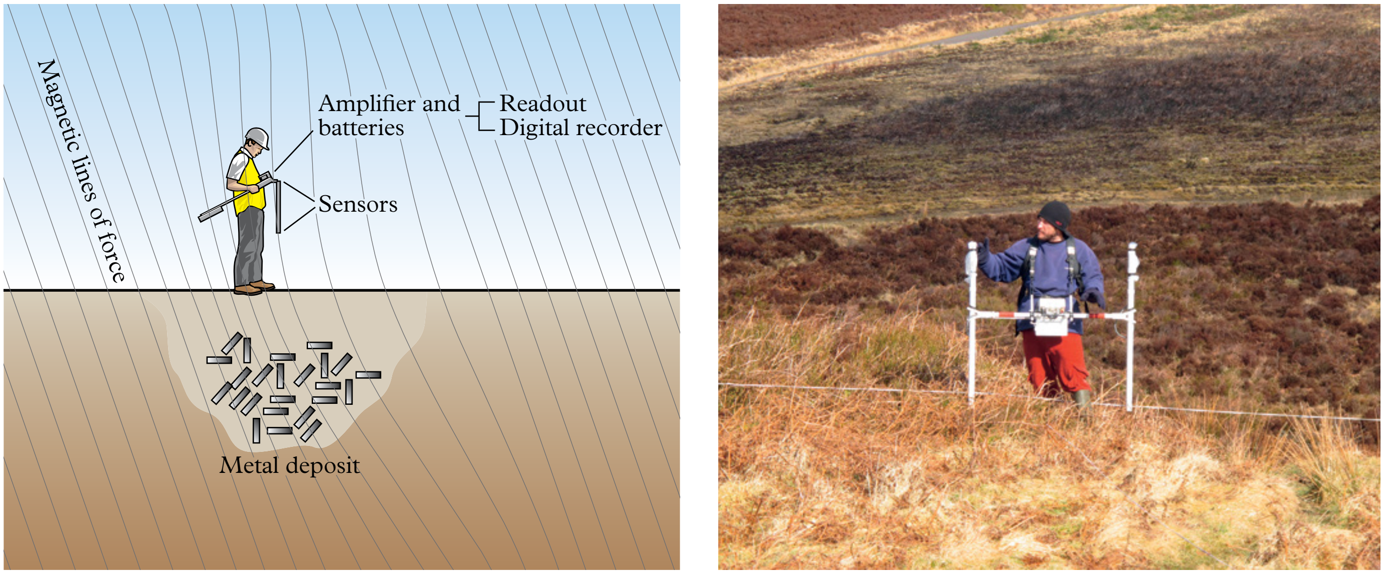


Figure 4 Person walking across the Earth's surface with a magnetometer

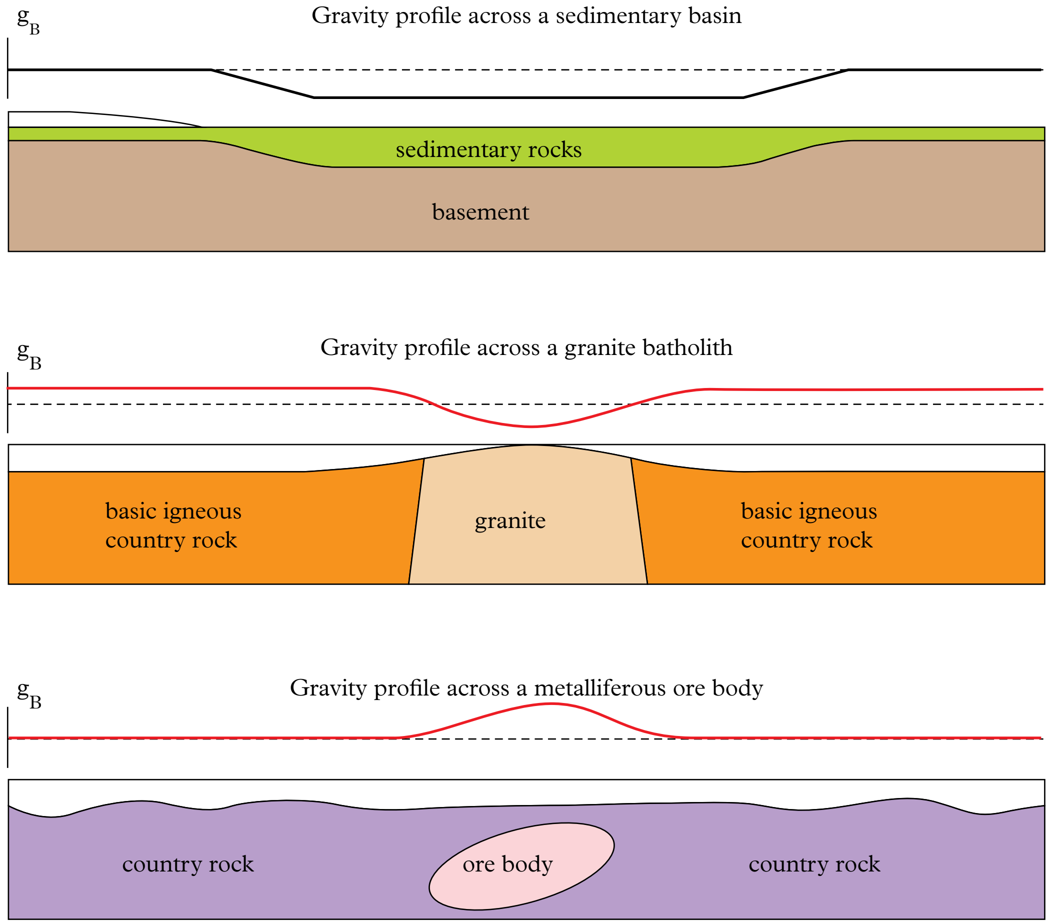


Figure 5 Granite and sedimentary rocks have lower gravitational fields than metal ores.

Figure 6 Helicopter with a front-end gravimeter

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 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.

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.

2.8 Test your skills and capabilities

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 needs above:

1 **Describe** one reason why the need for 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 the land surrounding your house was needed for this use, describe how this would change the way you live. **Describe** whether this changes the decision you made in question 3. **Explain** your reasoning.

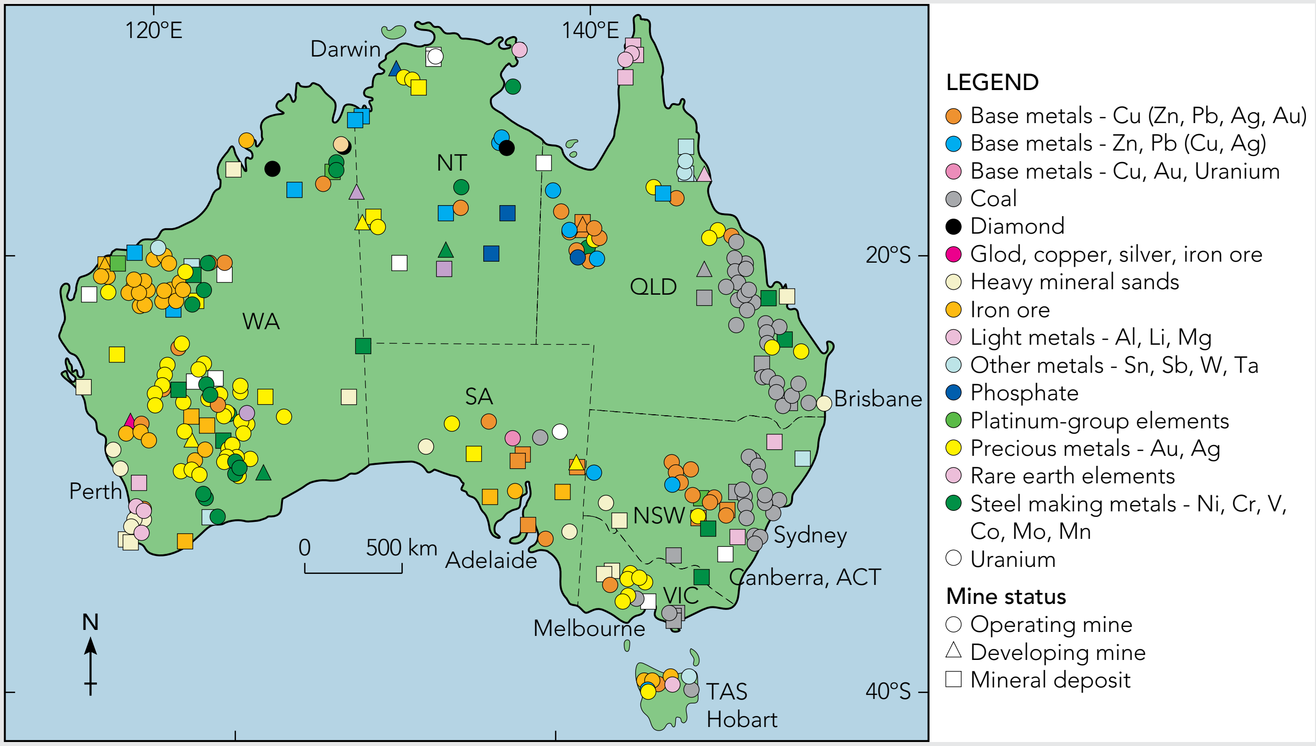


Figure 7 Geolocation has identified many different minerals across Australia.

CHAPTER 2 REVIEW

THE ROCK CYCLE

Retrieve

1 **Recall** the visual properties of rocks that can help identify them.

2 **Recall** the basis of rock classification.

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

4 **Define** the following terms.
  - **a** extrusive igneous rocks
  - **b** intrusive igneous rocks
  - **c** sediment

5 **Recall** the term used to describe a rock breaking apart because of daily heating and cooling.
  - **A** physical weathering
  - **B** chemical weathering
  - **C** biological weathering
  - **D** erosion

6 **Identify** the correct statement. 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.

Comprehend

7 Copy and complete the following sentences.
  - **a** _______________ are small pieces of organised particles that have smooth sides and sharp edges.
  - **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.

8 **Describe** the properties used by geologists to identify different rocks.

9 **Explain** why colour alone is not a reliable guide for identifying rocks.

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

11 **Explain** how sedimentary rocks form at the Earth's surface.

12 **Describe** the properties of ochre that make it valuable to First Nations Australians.

13 **Describe** how the different rock formations found in a cave (stalactites, stalagmites and columns) form.

14 **Describe** the relationship between weathering and erosion.

15 **Explain** why and how electromagnetic pulses detect metals.

Analyse

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

17 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, coarse grain size, hard
  - **c** fine grain size, soft, dark in colour

18 **Examine** the rock samples in Figures 1 and 2.
  - **a** Use Table 1 in Topic 2.1 to **identify** the rocks.
  - **b** **Explain** your responses.
  - **c** **Recall** the type of rock each sample is.
  - **d** **Consider** how their appearance relates to the way in which each was formed.

Figure 1 Rock sample 1

Figure 2 Rock sample 2

19 **Compare** obsidian and scoria rocks.

20 **Contrast** magma and lava.

21 Some famous works of art are made of marble (Figure 3).

a **Recall** the properties of marble.

b **Categorise** the properties of marble as being ideal for art works and not ideal for art works.

Figure 3 The famous marble statue of David, created by Michelangelo between 1501 and 1504

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

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

24 **Reflect on** why only simple fossils are found in the oldest types of rocks, whereas younger rocks have fossils of larger mammals.

Apply

25 There are no active volcanoes on the mainland of Australia, but there are still examples of igneous rocks throughout the country. **Suggest** what this implies about the history of volcanic activity in Australia.

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

27 **Propose** two ways to prevent water from eroding a memorial rock located in a town centre at the base of a hill.

Critical and creative thinking

28 Victoria, New South Wales and Queensland are susceptible to flood waters that can cause quick erosion. Based on the engineering solutions from Topic 2.6, **propose** what towns in flood-prone areas could do to protect themselves.

29 Figure 4 shows the Twelve Apostles found along the Victorian coast. Use this image to describe how these rocks were formed. **Create** a poster to show how the rocks were formed and how they 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.

30 **Create** a flow chart showing how fossils are formed.

31 Use the rock cycle (Figure 5 on page 44) to **create** a mind map linking the concepts you have learnt about in this chapter.

Include:

- the properties of rocks
- the formation of different rock types
- weathering and erosion and their prevention
- dating of rocks
- extraction of minerals.

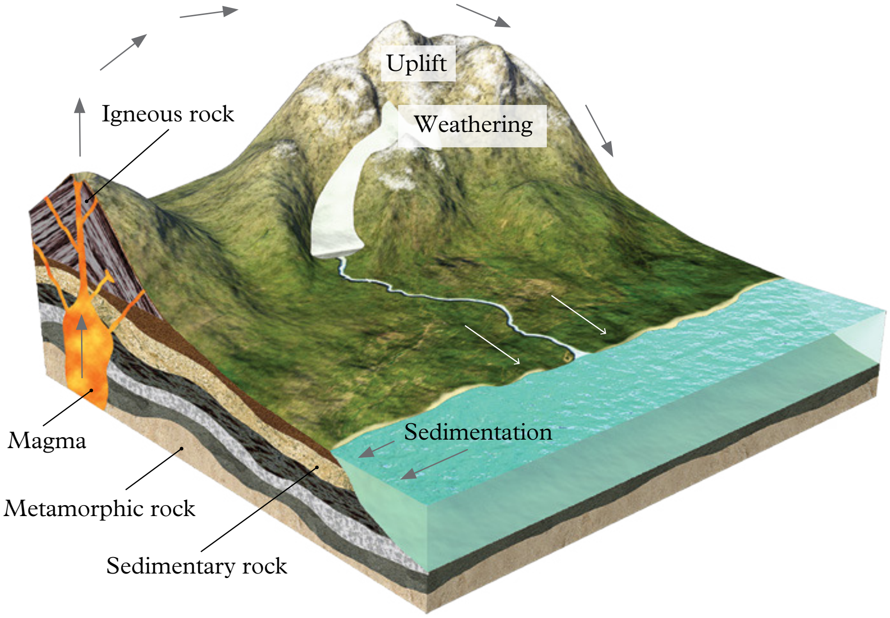


Figure 5 The rock cycle

Social and ethical thinking

32 Some people say that Australia is a huge quarry. This is because Australia mines so many minerals and sells them. Working on your own, **determine** 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.

Research

33 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

A gemstone is a mineral crystal that has been cut and polished. They are often used in jewelry. Some rocks, such as opal and obsidian, are not crystals but can also be polished and used for decoration.

- Describe what gemstones look like.
- Identify which gemstones are found in Australia.
- Select one of these gemstones and identify where in Australia they have been mined.
- Describe how a miner might have extracted this gemstone from the earth.

» 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.

Chapter checklist

Now that you have completed this chapter, reflect on your ability to do the following.

	I can do this.	I cannot do this yet.
• Recall the properties of rocks. • Identify rock samples, including by using a provided dichotomous key.	☐	☐ Go back to Topic 2.1 'Rocks have different properties'. Page 24
• 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 rocks with the way in which they are formed.	☐	☐ Go back to Topic 2.2 'Igneous rocks develop from magma and lava'. Page 26
• Describe the process of sedimentary rock formation. • Name several sedimentary rocks. • Explain the difference between biological and chemical rocks.	☐	☐ Go back to Topic 2.3 'Sedimentary rocks are compacted sediments'. Page 28
• 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 2.4 'Metamorphic rocks require heat and pressure'. Page 30
• Describe the rock cycle, weathering, erosion, onion-skin weathering and frost shattering. • Describe the differences between physical, chemical and biological weathering.	☐	☐ Go back to Topic 2.5 'The rock cycle causes rocks to be re-formed'. Page 32
• Describe the reasons for soil erosion. • Describe ways to reduce or prevent soil erosion.	☐	☐ Go back to Topic 2.6 'Weathering and erosion can be prevented'. Page 34
• Describe two different types of fossils. • Use fossil evidence to predict how and when rock was formed.	☐	☐ Go back to Topic 2.7 'The age of a rock can be calculated'. Page 36
• Describe the processes of geophysical and geochemical testing. • Evaluate the benefits and costs of mining.	☐	☐ Go back to Topic 2.8 'Science as a human endeavour: The locating and extraction of minerals relies on scientists'. Page 38

Check your Student obook pro for these digital resources and more:

Quizlet

Play a Quizlet game to test your knowledge.

Chapter quiz

Test your understanding of this chapter with the chapter review quiz.

CHAPTER

3

PLATE TECTONICS

3.1

The Earth is made of layers

> Define crust, mantle, core, tectonic plate and magma.

> Describe the layered structure of Earth.

3.2

Forces cause tectonic plates to move

> Define continental drift, sea-floor spreading, convection current, ridge push, slab pull, continental shelf and plate tectonics.

> Describe evidence that supports the theory of plate tectonics.

3.3

Boundaries between tectonic plates can be converging, diverging or transforming

> Describe the interactions between plates that occur at transforming, converging and diverging boundaries.

> Relate each of the types of boundaries with characteristic land formations.

3.4

Tectonic plates can be constructive or destructive

- Describe how the Hawaiian Islands may have formed from a hot spot.
- Provide examples of natural events that occur because of plate interactions.
- Relate constructive and destructive boundaries with diverging and converging boundaries.

3.5

Science as a human endeavour: Engineering solutions in earthquake zones

- Identify body waves and surface waves as the two main types of earth movements that occur during an earthquake and provide examples of each.
- Provide examples of structures and materials that can be used to limit the impact of earthquakes.

What if?

Clay plates

What you need:

Modelling clay

What to do:

1 Divide the clay into two equal portions.
2 Flatten out each portion to approximately 1 cm thick.
3 Gently slide the portions towards each other.

What if?

- What if one portion slides over the other?
- What if the two clay portions are jammed together?
- What if the two portions are moved apart?

3.1 The Earth is made of layers

Key ideas

- The Earth is made up of several layers.
- The centre of the Earth, or core, has two layers: the outer core of liquid iron and nickel, and the inner solid core.
- The next layer, the mantle, is made up of molten rock.
- The outer layer of the Earth that we live on is the crust, or lithosphere.

Learning intentions

By the end of this topic, you will be able to:

- define crust, mantle, core, tectonic plate and magma
- describe the layered structure of Earth.

core
the centre of the Earth

mantle
the layer of molten rock beneath the Earth's crust

What is the Earth made of?

Although the Earth is described as a solid planet, it began as a ball of molten materials. Scientists believe the Earth and other planets are the result of an explosion billions of years ago. According to this theory, the Earth began as a molten fragment from this explosion. The Earth's surface has continued to slowly change and is still changing – many rocks have worn down to form soil and sand, mountains and valleys have formed, and the land and oceans have changed shape. Some of this change is caused by weathering and erosion at the surface. Other changes are due to the movement of the molten rocks from deeper down, which in places push their way up to the surface and also move sections of the Earth's crust.

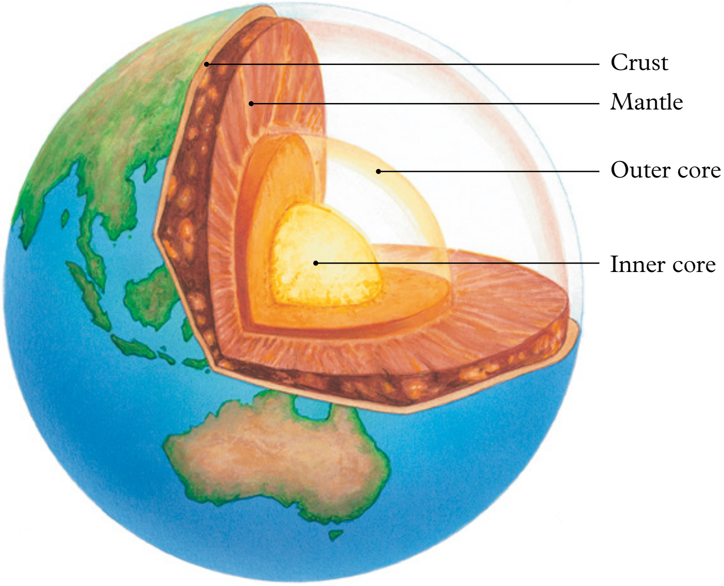


Figure 1 Layers of the Earth

If you could journey deep inside the Earth, you would find that it is made of several layers (Figure 1).

Core

The **core** is the centre of the Earth. It consists of the outer core and the inner core. The outer core is made mainly of metals, not rock; the main metal is iron, possibly with some nickel. It is very hot and liquid, with temperatures ranging from 4000°C to 6000°C. The heat comes from nuclear reactions, and some of the heat is left over from when the Earth was formed. The outer core gives the Earth its north and south poles and magnetic field. The temperature of the inner core is almost 10 000°C, but it does not melt or boil because of the force of the rest of the Earth pushing down on it. Of course, no geologist has ever seen the core. Even the deepest mines only penetrate a few kilometres of the Earth's crust.

Mantle

The **mantle** is between the core and the crust. It is about 2800 km thick. Temperatures near the crust are about 500°C and at the bottom of the mantle reach 3000°C. Although the bottom of the mantle is solid, nearer the top the rock slowly moves. The top part of the mantle is more like modelling clay than solid rock. It is the source of volcanoes and earthquakes.

EXPERIMENT

3.1A: Cooling and layers
Go to page **179**.

CHALLENGE

3.1B: Modelling the parts of the Earth
Go to page **180**.

Crust

The **crust** (or lithosphere) is the outer layer (7–50 km thick) of the Earth. It is a thin, brittle outer coating, like the shell of an egg. It is made up of rocks and minerals, and approximately 70 per cent of it is covered by oceans. The crust is not smooth: it has hills, mountains, valleys, oceans and deserts. It is thickest under the continents and thinnest under the oceans (Figure 2). Compared to the rest of the Earth's layers, the crust is very thin.

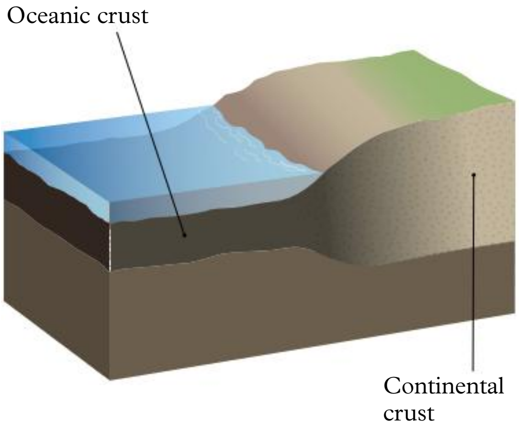


Figure 2 The Earth's crust is thinner beneath the ocean than beneath the continents.

The moving crust

The crust is broken into a number of pieces, called **tectonic plates**. These plates float on the semi-liquid **magma** at the top of the mantle. The speed of movement is similar to that of fingernail growth: between 1 cm and 10 cm per year. Sometimes the tectonic plates crash into one another, causing one plate to slide under the other. The plate on top buckles under pressure, pushing the land upwards (Figure 3). For example, the Indo-Australian Plate is sinking under the Eurasian Plate. This has caused the Eurasian Plate to buckle, pushing up the world's highest mountain range, the Himalayas (Figure 4).

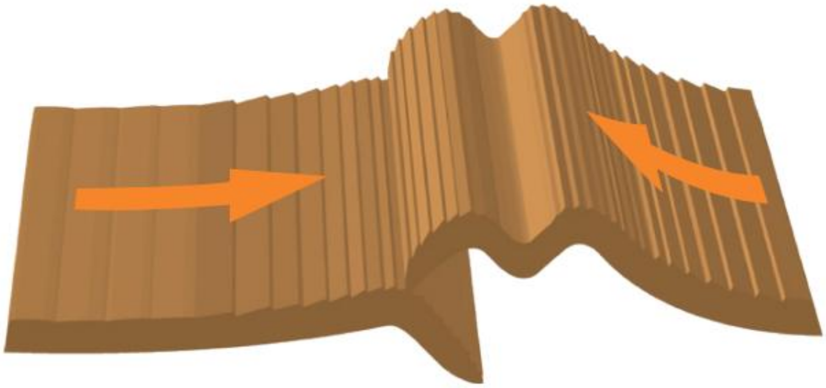


Figure 3 Colliding plates cause the Earth's surface to buckle.

Figure 4 The Himalayan Mountains have been pushed up by pressure from beneath the Earth.

crust
the lithosphere, or outer layer of the Earth

3.1 Check your learning

Retrieve

1 **Identify** the layer of the Earth that contains tectonic plates.

2 **Identify** the layer that contains magma.

Analyse

3 If the Earth's radius is about 6370 km, use the information about the crust and the mantle to **calculate** the thickness of the Earth's core.

Apply

4 'The Earth's crust is the same thickness everywhere.' **Evaluate** this statement (by comparing the approximate thickness of the Earth's crust at two extremes – the Andes and Victoria – and deciding whether the statement is likely to be correct).

5 Examine Figure 3. **Evaluate** whether this diagram could be used to model the formation of the Andes Mountains (by describing how the Andes are formed, comparing this to the diagram and deciding whether it is an accurate representation).

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

tectonic plate
a large layer of solid rock that covers part of the surface of the Earth; movement of tectonic plates can cause earthquakes

magma
semi-liquid rock beneath the Earth's surface

3.2 Forces cause tectonic plates to move

Learning intentions

By the end of this topic, you will be able to:

- define continental drift, sea-floor spreading, convection current, ridge push, slab pull, continental shelf and plate tectonics
- describe evidence that supports the theory of plate tectonics.

Key ideas

- Continental drift describes the drifting of the continents.
- Plate tectonics explains how and why the continents are moving.
- The forces involved in plate tectonics are convection current, ridge push and slab pull.

Many theories have tried to explain why there are earthquakes, mountains and deep-sea trenches over the surface of the Earth. One of the first theories was that the Earth was cooling down and therefore shrinking, causing 'wrinkles' to form on the surface. Like all theories, this idea was testable and was eventually changed and refined as new evidence became available. In this topic, you will see how the scientific hypothesis of continental drift was suggested, discounted, modified and then revived as **plate tectonics**.

Continental drift

One piece of evidence is the similarities in shape between the coastlines of Africa and South America. They seem to fit together like a jigsaw puzzle. In the early twentieth century, German meteorologist Alfred Wegener put this idea and other evidence into a book in which he outlined the theory of **continental drift**. He proposed that the continents once all fitted together in a giant continent known as Pangaea.

Wegener proposed that Pangaea was a supercontinent that existed 220 million years ago. When it started to break up, the continents slowly drifted apart as they moved through the oceanic crust. He supported his claims with the evidence of coastline fit, similar fossils, rocks and landforms created by glaciers in now widely separated continents, and the reconstruction of old climate zones.

For many years, other scientists did not support Wegener's theory of continental drift. It wasn't until after he died in 1950 that science developed the equipment to study smaller earth movements (seismometers) and landforms deep under the ocean (magnetometers). Maria Tharp and Bruce Heezen created the first map of the floor of the Atlantic Ocean. This map identified the Mid-Atlantic Ridge, the longest mountain range in the world. It just happens to be deep under the ocean.

Sea-floor spreading

The idea of **sea-floor spreading** was proposed by US geologist Harry Hess in 1962. His evidence came from the discovery of the Mid-Atlantic Ridge, a continuous mountain range in the middle of the Atlantic Ocean (Figure 3). Hess's original hypothesis was that the liquid mantle of melted rock (magma) under the tectonic plates was moving, creating convection currents. This moving mantle deep inside the Earth causes magma to rise in ridges under the ocean, pushing the tectonic plates to spread and move apart.

Convection currents

In liquids and gases, thermal energy can move by **convection**. The mantle closest to the Earth's core gains thermal energy.

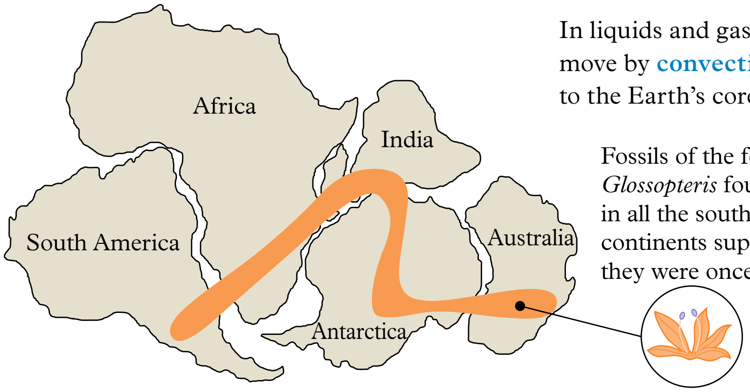
Figure 1 Alfred Wegener pioneered the theory of continental drift in his book *The Origin of Continents and Oceans*.

plate tectonics
the theory that the surface of the Earth consists of a series of plates that are continually moving due to convection, ridge push and slab pull

continental drift
the continuous movement of the continents over time

sea-floor spreading
the theory that the middle of the ocean is spreading apart, forming new oceanic ridges

convection
the transfer of thermal energy by the movement of molecules in air or liquid from one place to another



Fossils of the fern *Glossopteris* found in all the southern continents supports that they were once joined.

Figure 2 Given that the fossil fern *Glossopteris* cannot walk, swim or fly, how can its isolated occurrence in so many different parts of the world be explained?

CHALLENGE

3.2A: Reconstructing Pangaea
Go to page **181**.

CHALLENGE

3.2B: Milo convection currents
Go to page **182**.

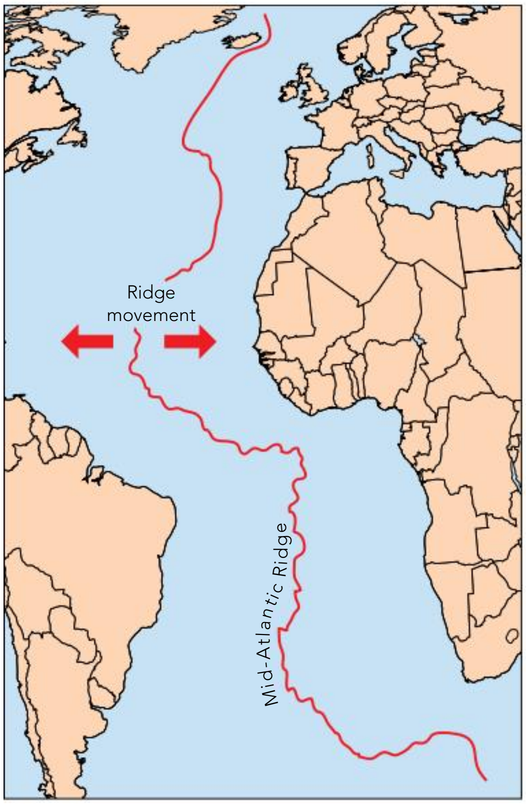


Figure 3 The Mid-Atlantic Ridge provided evidence of sea-floor spreading.

This means the molecules in the magma move faster. Because they move faster, they take up more space and become less dense. As a result, the heated magma near the core begins to rise to the surface, leaving room for cooler magma to take its place. The heated magma cools as it reaches the Earth's crust. As it cools, it is pushed to one side as more heated magma arrives. This causes the tectonic plates that form the crust to move. Cool magma is more compact and dense, and so it sinks, following the convection cycle. These tiny currents of force are called **convection currents**.

Ridge push

If convection currents occur within the Earth's mantle, then rising hot magma pushes up, creating a ridge crest. This usually occurs under the ocean. As the mantle rock moves away from the magma and ridge crest, gravity pulls the cooled ridges down and away from the hot magma still rising from the mantle. This pushes the ridges apart, forcing the new edges of the tectonic plate apart. This force is called **ridge push**.

Slab pull

Sometimes tectonic plates move towards each other. If one plate is denser (the particles are more tightly packed together), it will sink beneath the other plate. This is known as **subduction**. Sometimes the top, less dense plate will rise, forming a mountain range such as the Andes. Other times, the more dense plate will be pulled downwards, dragging down the rest of the tectonic slab. This force is called **slab pull**.

The movement of the plates explains the existence of landforms such as **continental shelves** and deep trenches in the ocean floor. It also explains how earthquakes and volcanoes are distributed, and the very young age of parts of the sea floor.

convection current
the current or flow of air or liquid that results from the transfer of thermal energy through convection

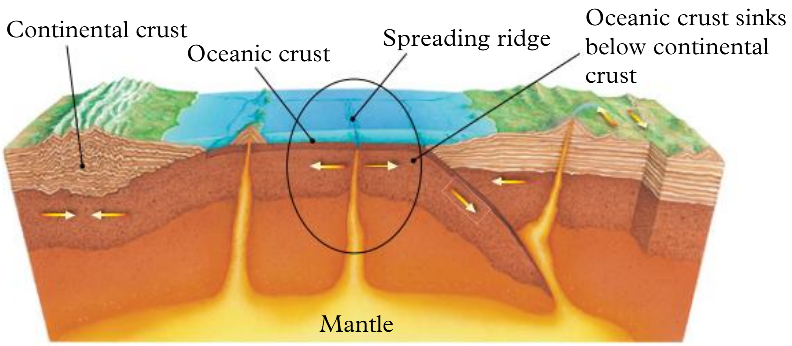
ridge push
the force pushing the edges of tectonic plates away from each other when a ridge crest has formed

subduction
the movement of one tectonic plate under another tectonic plate

slab pull
the force pulling a tectonic plate beneath a less dense tectonic plate

continental shelf
a flat area under shallow ocean water at the edge of a continent

Figure 4 Tectonic plate movement



3.2 Check your learning

Retrieve

1 **Define** the term 'slab pull'.

Comprehend

2 **Describe** how a ridge crest forms.

3 **Describe** how convection currents move in the mantle.

Analyse

4 Examine a world map. Apart from Africa and South America, **identify** the other regions of the world that look as if they could fit closely together.

5 **Contrast** (the differences between) continental drift and plate tectonics theories.

Apply

6 Considering the evidence that Wegener presented in support of continental drift, **discuss** why many scientists at the time may have rejected the idea.

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

3.3 Boundaries between tectonic plates can be converging, diverging or transforming

Learning intentions

By the end of this topic, you will be able to:

- describe the interactions between plates that occur at transforming, converging and diverging boundaries
- relate each of the types of boundaries with characteristic land formations.

Video 3.3
What happens when Earth's plates move?

Key ideas

- At transforming boundaries, tectonic plates slide past one another.
- At converging boundaries, plates come together, forming mountains or subducting.
- At diverging boundaries, tectonic plates move apart.

transforming boundary
the boundary between two tectonic plates that are sliding past each other

fault
a fracture in rock where the tectonic plates have moved

ocean trench
a deep ditch under the ocean along a tectonic plate boundary

Plate tectonics explains a wide range of features of the Earth. These features, once studied separately, can now be unified by a single concept: plate behaviour at plate boundaries (Figure 1). There are three general types of plate boundaries, based on the direction of plate movement.

Transforming boundaries

One plate can slide past another along a single fault line. This is called a **transforming boundary** (Figure 2).

A **fault** is a fracture in rock where movement has occurred.

The two plates involved in a transforming boundary can become jammed over a period of time until the pressure builds up and the plates slip. This slipping causes earthquakes, such as the large earthquake that destroyed San Francisco in 1906, when the rock of the transform fault slipped by up to 5 m.

Plate material is not created or destroyed: the plates just slide against each other.

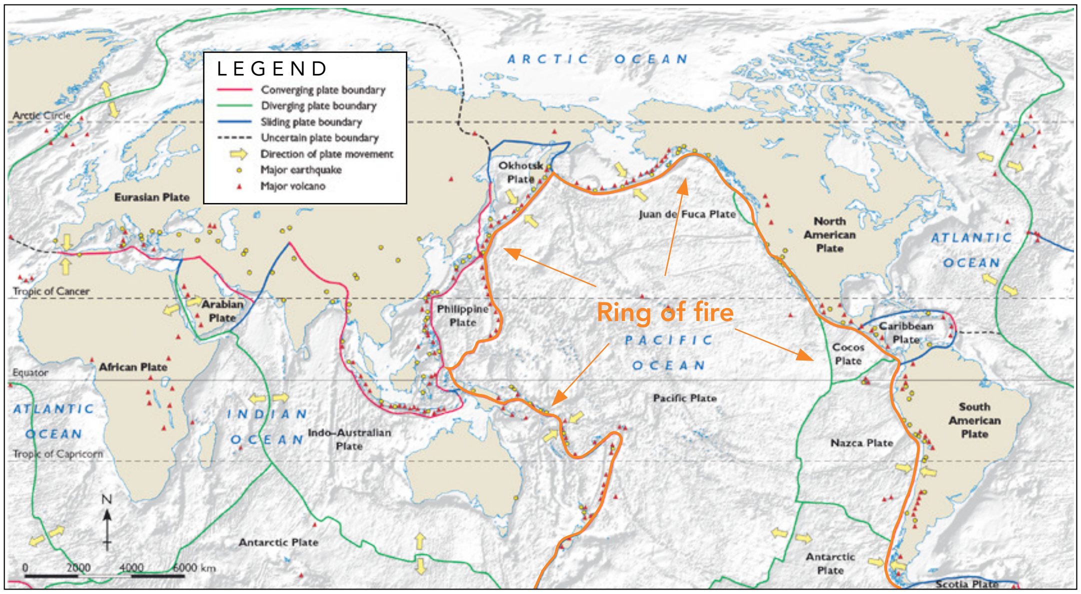


Figure 1 The ring of fire is an area around the Pacific Ocean where a large number of volcanoes are found. This provides hints of a tectonic boundary.

CHALLENGE

3.3: Modelling plates
Go to page **183**.

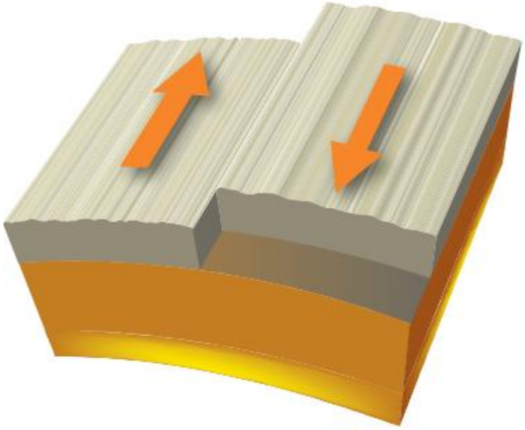


Figure 2 Transforming boundary: one plate slides against another

Figure 3 Satellite image of the Southern Alps, New Zealand. The Alpine Fault, a transforming boundary, runs along the western edge of the snowline on the South Island.

Converging boundaries

At converging plate boundaries, two plates move towards each other. There are generally three types of **converging boundaries**, depending on the plates involved. Mountain ranges, volcanoes and trenches can all be formed by converging boundaries. Many of the world's major landforms are formed by the collision of plates at converging boundaries.

Ocean-to-continent collision

When oceanic crust collides with continental crust, the denser oceanic landform is subducted or pushed downwards into the mantle. The top crust is pushed upwards and creates a line of mountains along the crumpled edge (Figure 5). It can also create volcanoes as heat rises through cracks in the crust. An **ocean trench** may form at the line of plate contact.

Figure 4 The San Andreas Fault, which runs along the western coast of California, USA

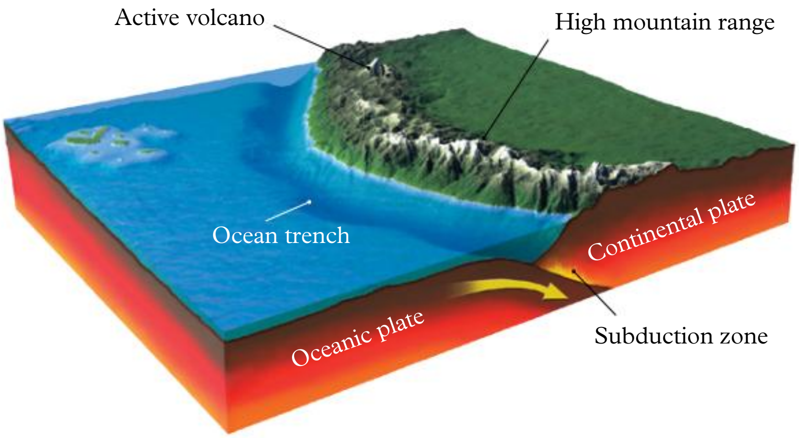


Figure 5 Ocean-to-continent collision causes subduction, and creates mountains, volcanoes and ocean trenches.

Continent-to-continent collision

When two continental plates collide, they have similar densities, so no subduction takes place. Instead, the edges of the two plates crumple and fold into high mountain ranges (Figure 6).

converging boundary
the boundary between two tectonic plates that are moving together

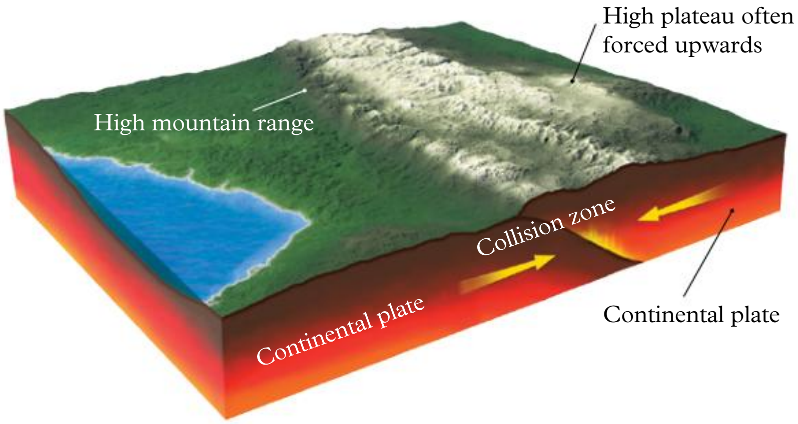


Figure 6 Continent-to-continent collision creates high mountain ranges.

Ocean-to-ocean collision

When two oceanic plates collide, the older, denser crust subducts below the newer crust, creating a deep ocean trench.

The subduction also creates a line of undersea volcanoes that may reach above the ocean surface as an island arc (Figure 7).

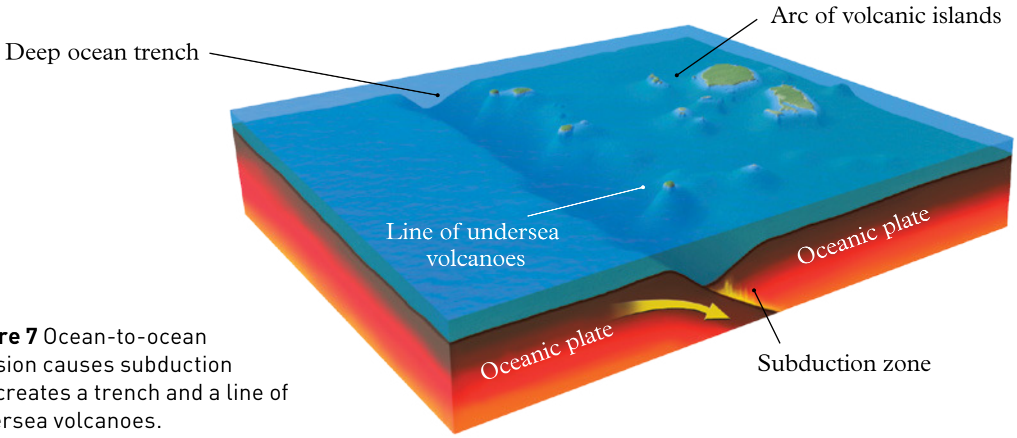


Figure 7 Ocean-to-ocean collision causes subduction and creates a trench and a line of undersea volcanoes.

Diverging boundaries

diverging boundary
the boundary between two tectonic plates that are moving apart

rift valley
a deep valley that forms as a result of tectonic plates moving apart on land

mid-ocean ridge
a series of underwater mountains that form as a result of tectonic plates moving apart and allowing magma to rise to the surface

Diverging boundaries are plate boundaries that are moving apart. They form different features than those of converging and transforming boundaries. These spreading boundaries can occur in the middle of the ocean or in the middle of land. The breaking up of the supercontinent Pangaea was probably due to diverging plate boundaries.

Hot rising mantle rock from deep within the Earth might be the first step in a continent breaking apart. As the mantle rock rises, the continental crust is lifted and thins out. Cracks form and large slabs of rock sink into the Earth, forming a **rift valley** like those found in East Africa.

Figure 8 The East African rift valleys may represent the initial stages of the breaking up of a continent.

Making oceans

As the divergence process continues, the continental crust separates and a narrow sea or lake may form. The Red Sea between the Arabian and African Plates is thought to be a diverging boundary at this stage of development (Figure 9). Eventually, oceans are formed and a **mid-ocean ridge** is created (Figure 10).

Mid-ocean ridges are very wide, up to 4000 km. Sea-floor spreading occurs at a rate of only 5 cm per year, but none of the ocean floor is dated as older than 180 million years.

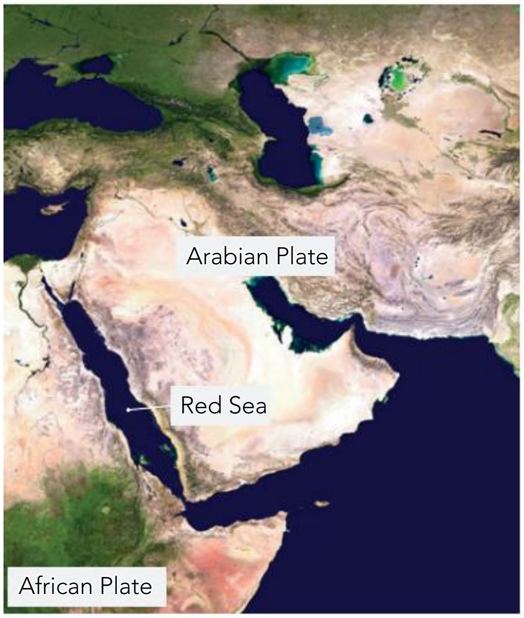


Figure 9 The Red Sea has formed as the African and Arabian Plates have diverged.

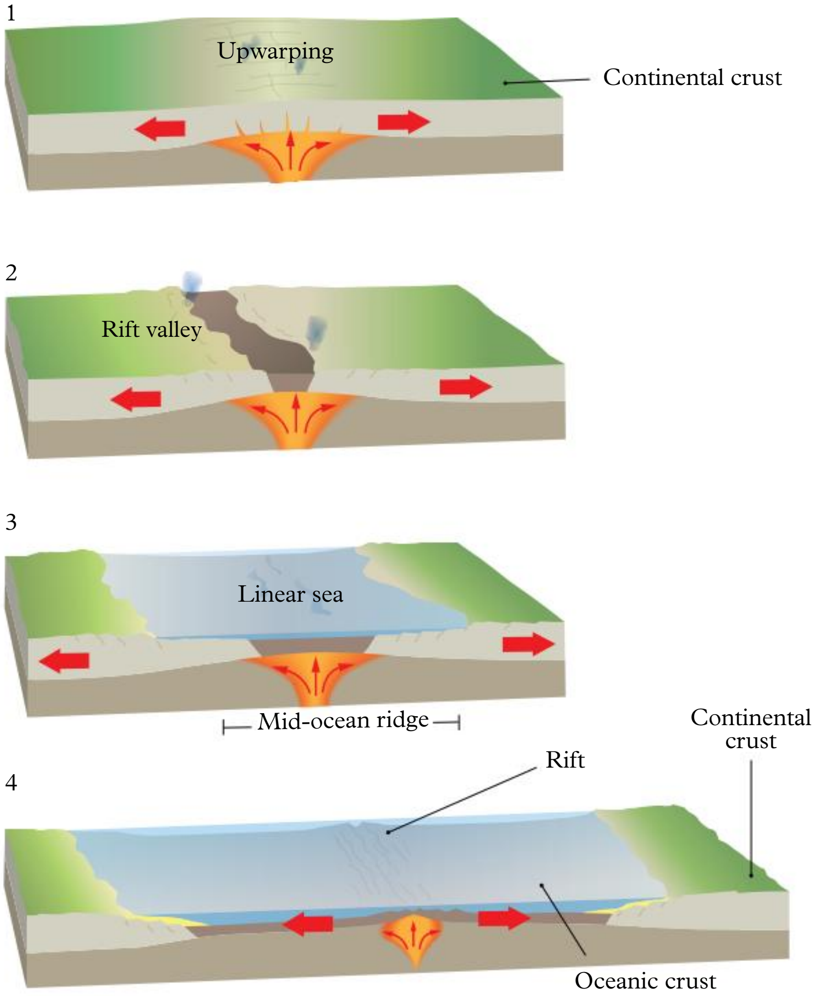


Figure 10 How diverging boundaries form oceans

3.3 Check your learning

Retrieve

1 **Identify** the factor that determines which plate subducts at a converging boundary.

Comprehend

2 **Describe** the type of plate movement that happens at a transforming boundary.

3 **Describe** what causes the continental crust to spread and break at a diverging boundary.

4 Use Figure 1 to **describe** where the major mid-ocean ridges are located.

5 Use Figure 1 to **describe** where the diverging plate boundaries are located.

6 **Explain** how diverging boundaries can produce earthquakes and volcanic activity.

7 Transforming boundaries are sometimes called strike–slip fault zones. **Explain** why both names are appropriate.

Analyse

8 Use the location of the tectonic plates in Figure 1 to **describe** the location of volcanoes. **Compare** (the similarities and differences between) these and the location of earthquakes.

Quiz me

Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

3.4 Tectonic plates can be constructive or destructive

Learning intentions

By the end of this topic, you will be able to:

- describe how the Hawaiian Islands may have formed from a hot spot
- provide examples of natural events that occur because of plate interactions
- relate constructive and destructive boundaries with diverging and converging boundaries.

Key ideas

- Movement of tectonic plates can cause destructive earthquakes or tsunamis.
- Molten mantle can escape from volcanoes and become lava.
- Lava can form new islands.

The boundaries between the tectonic plates create a lot of pressure as they try to move against each other. This pressure can be released suddenly in the form of an earthquake, which in turn can form a tsunami.

Earthquakes can cause tsunamis

Undersea earthquakes can move the sea floor and push up the water to form a wave known as a **tsunami** (Figure 3). An earthquake in northern Japan in 2011 was magnitude 9.0 on the Richter scale. The earthquake was centred 140 km off the coast and sent a 10 m high wall of water towards coastal towns and cities.

The tsunami wave also travelled away from Japan, right across the Pacific Ocean, and was experienced as far away as North and South America, the Pacific Islands and even in northern Australia as a small wave.

Japan is the most seismically active country in the world because it lies near the boundaries of three tectonic plates: the Pacific, Eurasian and Philippine Plates. The force of a tsunami can be enormous, enough to demolish buildings, and lift cars and even small ships.

Volcanoes and tsunamis

Volcanoes pose great danger to those who live near them. The volcanic eruption of Krakatoa, Indonesia, in 1883 caused a tsunami that raced across the ocean and crashed onto nearby islands.

Figure 1 The San Francisco earthquake in 1906 destroyed much of the city.

tsunami
a series of large waves that result from an underwater earthquake

Figure 2 Volcanic eruptions can cause tsunamis.

CHALLENGE

3.4A: Volcanic bubbles
Go to page **184**.

CHALLENGE

3.4B: Modelling a tectonic boundary
Go to page **185**.

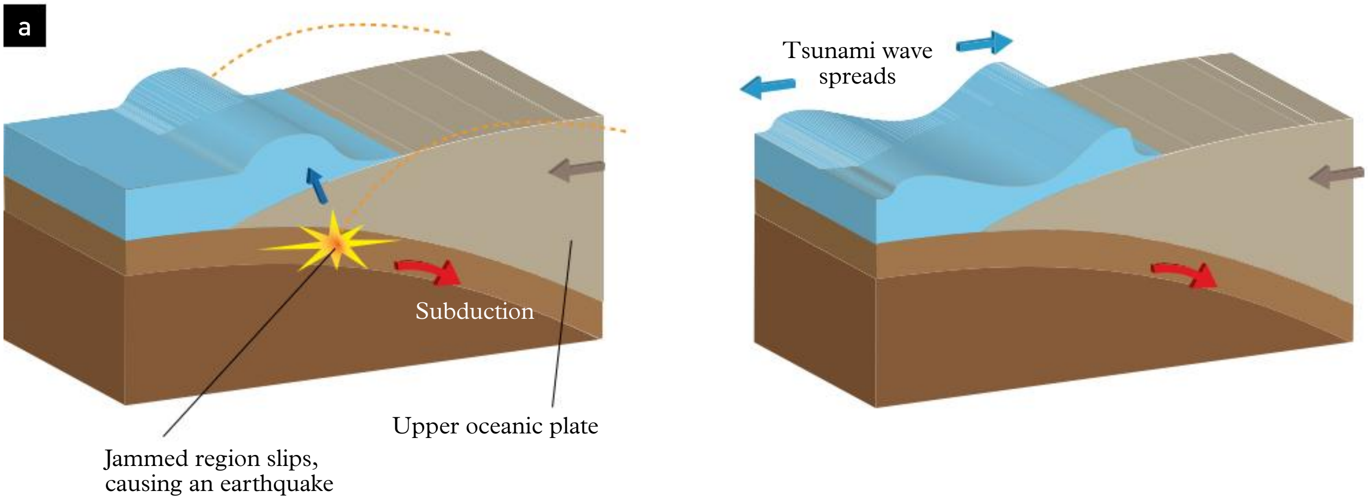


Figure 3 a How an earthquake causes a tsunami **b** The aftermath of the earthquake and tsunami in northern Japan in 2011

The tsunami killed 36 000 people. Krakatoa's blast was heard 5000 km away and ash rose 80 km into the atmosphere.

Volcanic eruptions spew lava and ash onto the surrounding land. When this material is broken down by the action of wind and water, and mixed with organic material from plants and animals, it forms some of the richest soil in the world. So, in spite of the dangers, people continue to live near volcanoes because of the fertile soil they provide.

Hawaiian Islands

The Hawaiian Islands are in the centre of the Pacific Plate (Figure 1, page 52). Hawaii is not near a mid-ocean ridge, yet it has frequent volcanic activity. Most geologists believe this volcanic activity is caused by the movement of the Pacific Plate over a 'hot spot' beneath the plate. This is where a plume of hot magma from the mantle comes up through a thin area in the crust and creates a volcano.

In the case of the Hawaiian Islands, the hot spot formed an undersea volcano (Figure 4). Over time, the volcano grows until it pokes above the ocean surface and creates an island. As the plate moves over the hot spot, other islands are formed over millions of years and an island ‘chain’ is created.

The centre of a plate usually lacks earthquakes, volcanoes or folded mountain ranges because it is a long way from a plate boundary, although these landforms are still possible in areas of weakness or thinning. The theory of plate tectonics and what happens at the plate boundaries corresponds with the distribution of earthquakes and volcanoes around the world. Consider Australia’s location and the limited number of earthquakes and extinct volcanoes on our continent.

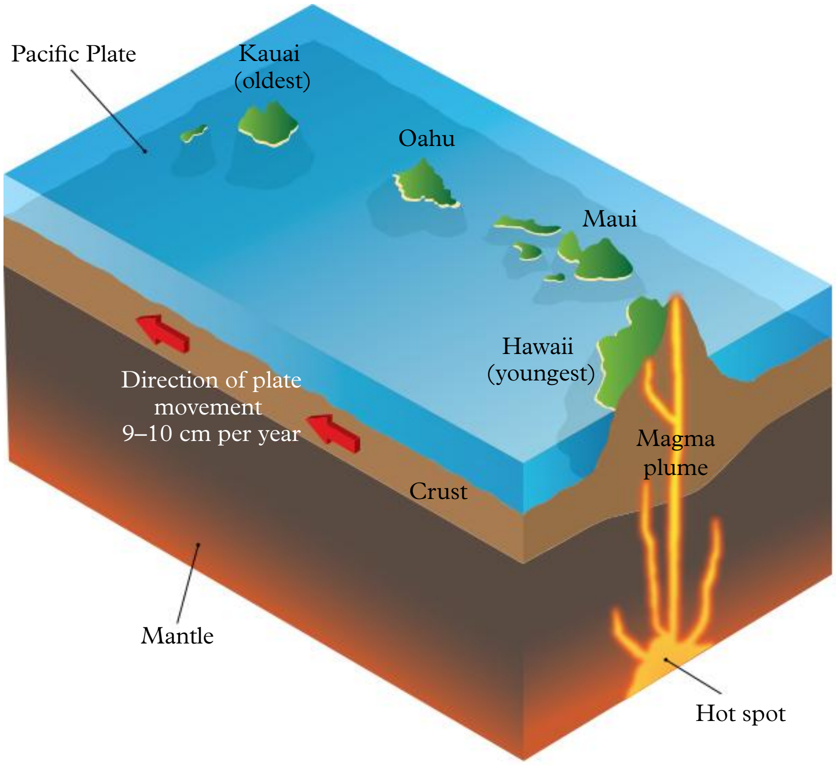


Figure 4 How the Hawaiian Islands were formed. (Only the largest islands are shown.) Hot spots result from magma pushing through thin areas of the Earth’s crust.

Figure 5 Evidence of volcanic activity on the Hawaiian islands: **a** rocks that appear to flow into the sea formed from old lava flows, **b** mountains rising out of the sea, **c** and **d** volcanic rock formations, **e** steam rising from craters and **f** lava flowing from active vents

Earthquakes in Australia

Unlike New Zealand, Australia is located in the centre of the Indo-Australian Plate. It is thought that the plate formed when two smaller plates fused, 43 million years ago. Although we think of tectonic plates as being fixed, two large earthquakes (measuring 8.6 and 8.2 on the Richter scale) beneath the Indian Ocean in 2012 suggest that these two plates may be breaking apart again. The age of the tectonic plate on which Australia is located, and Australia's central position on the plate, have both resulted in minimal earthquake activities.

However, there are still more than 300 magnitude 3.0 or greater earthquakes in Australia every year. Our plate, the Indo-Australian Plate, is moving north towards the Eurasian, Philippine and Pacific Plates. This creates stress within our plate, and release of this stress creates earthquakes.

One of Australia's worst earthquakes was of magnitude 5.6 and struck near the city of Newcastle in New South Wales on 28 December 1989. It killed 13 people and injured 160. Larger earthquakes have occurred in Australia, but the damage depends on how close they are to the surface and to large cities. A huge earthquake in the outback is unlikely to cause large loss of human life. Figure 6 shows Australia's earthquake and tsunami risk.

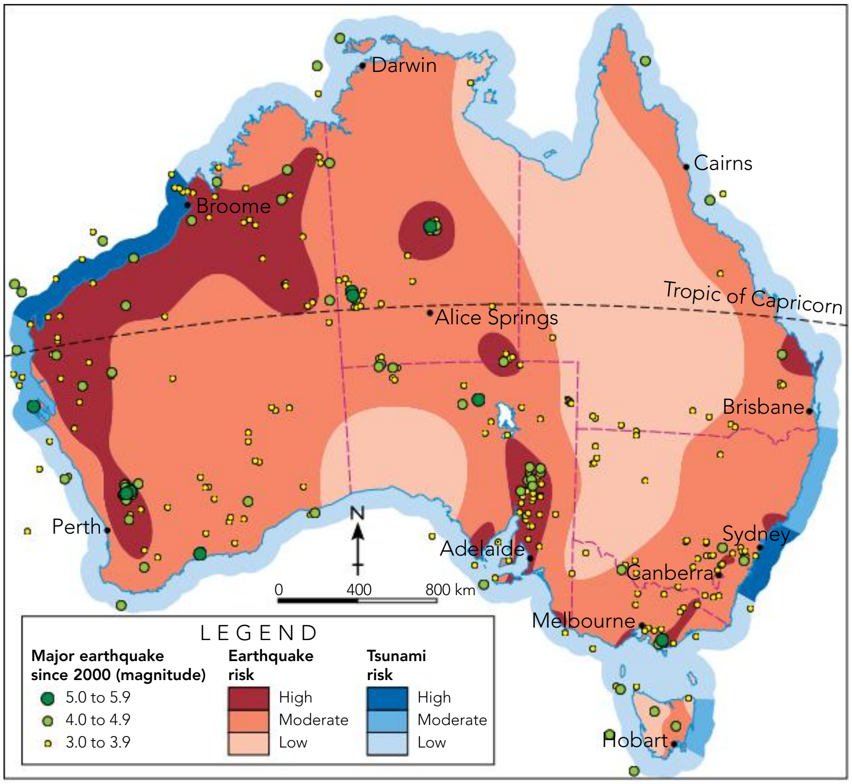


Figure 6 Australia: earthquake and tsunami risk

3.4 Check your learning

Retrieve

1 **Recall** two ways that the movement of tectonic plates can be destructive.

Comprehend

2 **Describe** a tsunami.

3 **Describe** where most earthquakes occur. **Explain** why earthquakes occur in these regions.

4 **Explain** how the movement of tectonic plates can be constructive.

5 **Explain** why there are few large earthquakes in Australia.

Apply

6 Like Australia, the Hawaiian Islands are in the centre of a tectonic plate. **Discuss** why the Hawaiian Islands have volcanoes and Australia does not.

Quiz me

Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

//SCIENCE AS
A HUMAN ENDEAVOUR//

3.5 Engineering solutions in earthquake zones

Learning intentions

By the end of this topic, you will be able to:

- identify body waves and surface waves as the two main types of earth movements that occur during an earthquake and provide examples of each
- provide examples of structures and materials that can be used to limit the impact of earthquakes.

The movement of tectonic plates can have devastating effects for those living on the surface of the Earth. There are two main types of earth movement that can result from releasing the pressure built up from the tectonic plates moving against each other. Body waves are earth movements that can travel through the body of the Earth and are not trapped near the surface. Surface waves can only travel along the surface of the Earth.

Primary body waves

The primary body waves are pressure waves (P-waves) that can travel through solid rock, liquid ocean and the gases of the atmosphere. Each wave causes the particles to compress and move close together, before expanding out again (Figure 1). These sound waves are the fastest moving of the earthquake waves (1600–8000 m/s) and move in the direction of the earth movement. Because they are so fast moving, they are often the first waves noticed in an earthquake.

Secondary body waves

Secondary body waves are also called shear or shaking waves (S-waves). S-waves can only move through solid earth. Some S-waves will move the earth from side to side, while others will move the earth up and down (Figure 2). These waves move much slower than P-waves (900–4500 m/s) but are more destructive as they can shake the whole landscape and can cause buildings to collapse.

The speed of P- and S-waves will vary according to the density and elastic properties of the Earth.

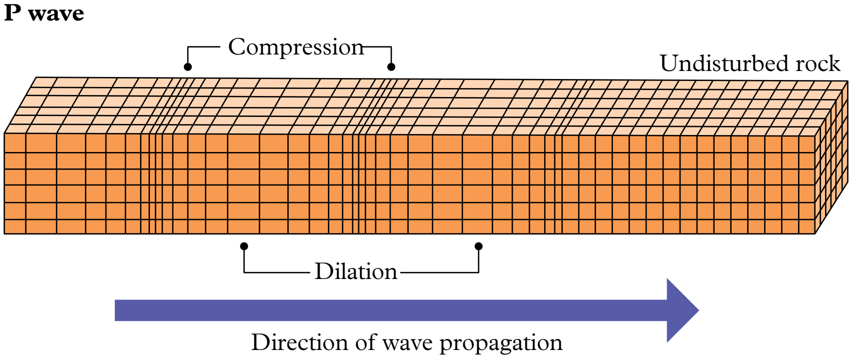


Figure 1 P-waves cause the solids, liquids and gases in the Earth to compress and expand.

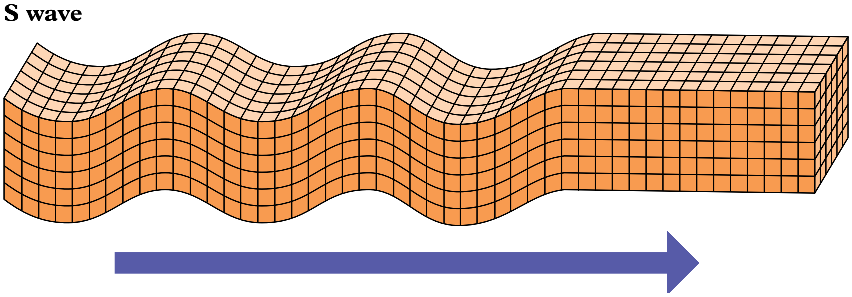


Figure 2 S-waves move from side to side or up and down. They are more destructive than P-waves.

Rayleigh surface waves

Like all surface waves, Rayleigh waves can only move along the surface of the Earth. These waves cause the ground to move like waves or ripples on the ocean (Figure 3). They can move both up and down or side to side. People who have observed Rayleigh waves have described them causing parked cars to 'bob up and down like corks floating on the ocean'. These waves are slower than S-waves.

Love surface waves

Love waves only move the Earth from side to side (Figure 4). They travel faster than Rayleigh waves but slower than body waves. Their movement can cause a lot of damage to the foundations of buildings.

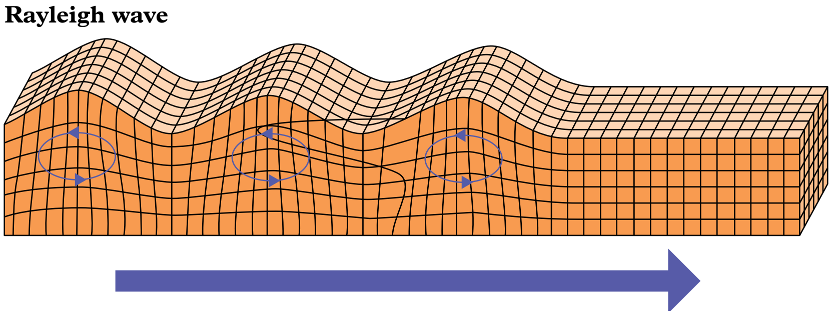


Figure 3 Rayleigh surface waves cause objects to bob up and down like corks.

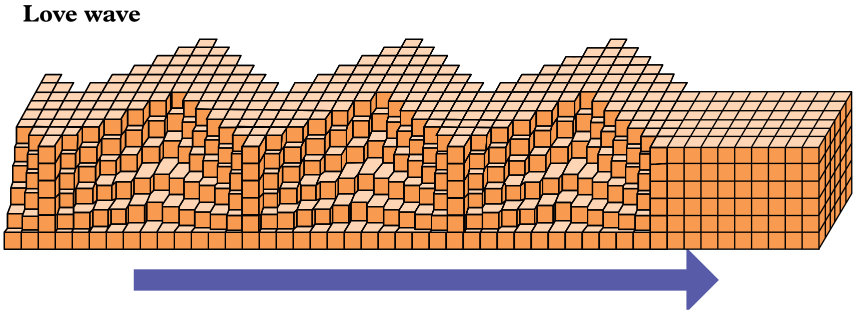


Figure 4 Love surface waves cause the Earth to move from side to side, causing damage to building foundations.

Liquefaction

During earthquakes, the particles in the soil compress under the force of gravity, squeezing the space between particles. This causes the liquid caught in these spaces to be compressed, building up the pressure. When the pressure increases above a certain point, the soil particles start floating, and the ground starts acting like a liquid. This is called liquefaction. This is why some objects will sink during an earthquake (Figure 5), while other less dense particles will rise to the surface. You may have seen this when standing on a wet beach: if you wiggle your toes, your feet will sink.

Figure 5 Liquefaction is when the soil acts like a liquid during an earthquake.

Designing for earthquakes

There are several factors that need to be considered when designing structures for earthquake zones. Liquefaction and Love surface waves can damage the foundations of a building or bridge. This can be minimised by building flexible pads into the foundations. This allows the foundations to move during an earthquake, absorbing the energy of the earthquake while the building above stays relatively still.

Engineers use a variety of ways to stabilise tall buildings during an earthquake. Some suspend large heavy balls in the centre of the building. When a building begins to sway, the ball moves in the opposite direction (like a pendulum) to stabilise the building. Some engineers place dampers between the columns and beams at each floor of the building (Figure 6). Each damper can act like a shock absorber in a car, reducing the amount the building moves.

Many buildings in earthquake zones are also reinforced by adding cross braces (diagonal steel beams that help the building to keeps its shape) and diaphragms (flat structures that transmit the horizontal movement away from the building frames).

Figure 6 Earthquake dampers reduce the movement of a building like a shock absorber reduces road bumps in a car.

CHALLENGE

3.5: Design an earthquake-proof house
Go to page **186**.

Earthquake-resistant materials

The materials used in the building can also help the building control the movement energy in an earthquake. The materials used must be flexible enough to bend without breaking. Concrete and brick are too brittle and will usually crack and fall. While steel and wood have been used in many buildings for the past 50 years, there are many old and new materials that may be more appropriate. Bamboo has much greater flexibility and is able to return to its original shape much better than steel and wood. It is very light as a building material, reducing the weight on the shaking foundations of the building. This also means that there is less risk to inhabitants if the building were to fall.

The multiple ties that are used in the construction of bamboo buildings can also help to maintain the flexibility of the structure.

Understanding of the properties of the traditional bamboo buildings constructed in earthquake zones has encouraged engineers to produce and use new materials with the same strength and flexibility. Strategies include:

- coating brickwork in acrylic-silicone paint resin and glass fibres to support flexibility
- combining cement with polymer-based fibres, fly ash or other additives to make it more flexible
- laminating wood by gluing layers of wood together so that the grain is parallel to each other.

These strategies work together to limit the damage caused by earthquakes and minimise the number of people killed each year.

3.5 Test your skills and capabilities

All scientists make predictions and hypotheses that can be evaluated to determine their truth or viability. This requires criteria to be developed and applied, to test the limitations of the model and determine whether modifications are needed.

Answer the following questions to critically **evaluate** the claim that all buildings in an earthquake zone should be made of bamboo.

1. **Identify** the types of earth movements that a building in an earthquake zone could experience.
2. **Identify** the ways a building in an earthquake zone could move.
3. **Describe** how this movement would affect the materials in the building.
4. **Compare** (the similarities and differences between) the flexibility and strength of different building materials including concrete, bricks, wood, steel and bamboo.
5. **Contrast** your descriptions of earth movement in question 2 with the material comparison in question 4.
6. **Identify** three questions you could ask an engineer about a building design in an earthquake zone.
7. **Investigate** one form of evidence or data that would cause you to disagree with the claim that all buildings in an earthquake zone should be made of bamboo.
8. **Determine** if you agree or disagree with the claim that all buildings in an earthquake zone should be made of bamboo.

CHAPTER 3 REVIEW

PLATE TECTONICS

Retrieve

1 **Identify** which two of the following have led to our understanding of plate tectonics.
- A continental drift
- B subduction
- C sea-floor spreading
- D magnetometers

2 **Identify** the type of plate collision where subduction is most likely to occur.
- A continent to mantle
- B continent to continent
- C ocean to ocean
- D ocean to continent

3 **Identify** the type of natural disaster that can be caused by an undersea earthquake.
- A hurricane
- B volcanic eruption
- C tsunami
- D bushfire

4 **Recall** the evidence that Alfred Wegener used to support his theory of continental drift.

5 **Define** the following terms.
- a subduction
- b slab pull
- c diverging boundary
- d converging boundary
- e ridge push
- f convection
- g sea-floor spreading

Comprehend

6 **Describe** Pangaea and what happened to it.

7 **Describe** the three forces that move the tectonic plates over the surface of the Earth.

8 **Describe** the cause of major volcanic eruptions and earthquakes.

9 Most earthquakes occur at plate boundaries. **Explain** how an earthquake can occur in the middle of a plate.

10 **Explain** why continental crusts cannot be subducted.

11 **Explain** how sea-floor spreading accounts for the young age of the sea floor.

12 **Explain** why modern GPS systems are useful for predicting future plate movements.

Analyse

13 The Himalayas formed when India collided with the Eurasian Plate. Mount Everest, the highest mountain on the Earth, is 8848.86 m high and continues to be uplifted at a rate of about 1 cm per year. Assuming there is no erosion, **calculate** the height of Mount Everest in 1 million years if it maintains its current rate of increase.

Figure 1 The Himalayan mountain peaks

14 Examine Figure 2, which shows a topographic image of the Mid-Atlantic Ridge. **Consider** how this provides evidence of sea-floor spreading.

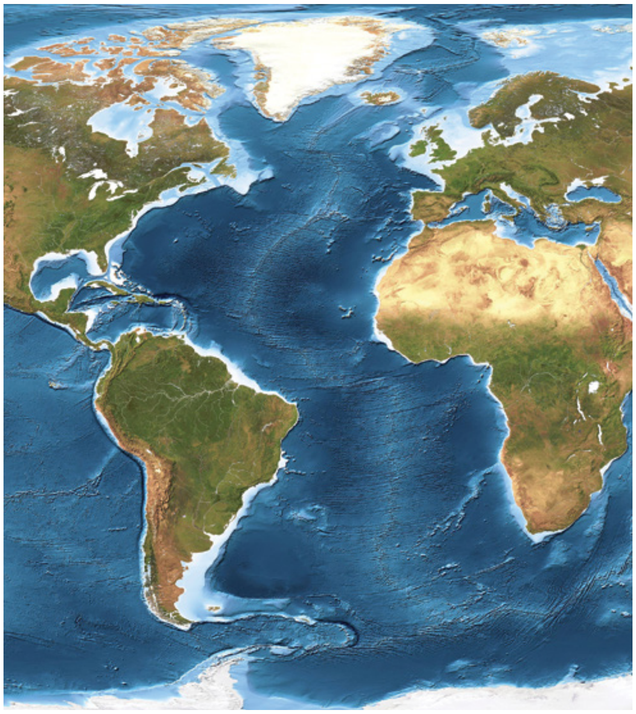


Figure 2 The Mid-Atlantic Ridge

15 If part of the Pacific Plate is moving at a rate of 10 cm per year, **calculate** how far it would move in:

a 100 years

b 10 000 years

c 1 million years.

16 **Contrast** the different layers of the Earth.

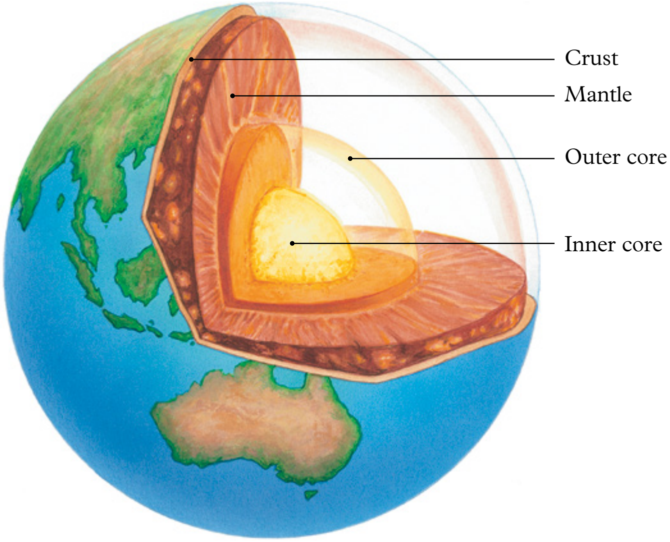


Figure 3 Layers of the Earth

17 **Connect** the following terms with their definitions.

Term	Definition
Mantle	Central part of the Earth
Crust	Layer of hot, semi-molten rock below the crust
Oceanic crust	Theory that states that the continents move through oceanic crust
Continental crust	Theory that describes why large plates of the Earth's crust gradually move
Plate tectonics	Less dense crust containing continents
Tectonic plate	Hot liquid rock that comes up from the mantle
Continental drift	Thin, semi-rigid outer layer of the Earth
Convection current	Large area that may include continent and sea floor
Magma	Dense crust under the sea floor
Core	Movement of liquids or gases caused by the rising of hot material

Apply

18 If Australia moves north to collide with Indonesia and Malaysia, **determine** the geographical features that will form and how our climate will change.

19 Once there was one supercontinent called Pangaea. Initially it split into two. One part, Laurasia, moved north while the other, Gondwanaland, moved south. Laurasia gave rise to Europe, Asia and North America. Gondwanaland gave rise to Africa, South America, Australia, India and Antarctica. **Discuss** the climate changes each continent faced as it drifted to its current position, and **explain** why, today, many plants and animals share physical similarities with those that originally inhabited the Gondwanaland subcontinents.

Social and ethical thinking

20 In 2009 there was a series of small earth tremors in the Italian city of L'Aquila. Six scientists (three seismologists, a vulcanologist and two seismic engineers) provided advice to the city that an ongoing series of small- and medium-sized tremors did not necessarily mean a large earthquake was going to occur. As a result, the citizens did not take precautions, and many were indoors on the night the 5.9 magnitude earthquake hit. The scientists were charged with manslaughter for the deaths of 308 people, because they had failed to predict the earthquake. Their initial conviction was eventually overturned. **Evaluate** the fairness of this trial by:

- describing how the local townspeople would have reacted if the scientists had warned of the impending earthquake
- describing how the local townspeople would have reacted if the scientists had not offered any advice
- describing the accuracy of earthquake predictions
- deciding whether the scientists should have offered any advice to the townspeople.

Figure 4 The earthquake that struck L'Aquila in 2009 was one of the deadliest in Italy.

Critical and creative thinking

21 **Create** a poster or multimedia presentation about a famous earthquake or volcanic eruption. **Describe** the facts of the earthquake or volcanic eruption and what plate movement caused it, along with the social, environmental and economic impacts and the subsequent recovery process.

22 The Mariana Trench is located where the Pacific Plate is subducting under the Mariana Plate. Its average depth is 11 km below the surface of the water. Surprisingly, ocean explorers have found life at the bottom of the Mariana Trench. **Investigate** the organisms that live so deep and how they survive.

23 Imagine you could travel into the future, to a time when your local environment is drastically different from how it is today. Base your imagined scenario on the plate movements of the Australian continent. **Create** a travel brochure for a future tourist destination or journey on this new Earth.

24 Imagine you are an engineer designing a building for an area that often experiences earthquakes. **Discuss** the type of earth movements that could be caused by the earthquakes and **determine** what materials you will use to help limit the impact of the earthquakes on your building.

Research

25 Choose one of the following topics to research. Some questions have been included to get you started. Present your findings in a format of your own choosing (such as filming a documentary), giving careful thought to the information you are communicating and your likely audience.

» Subduction zones

The subduction of one plate under another is well understood by scientists today, but how this process begins is not.

- Explain what geologists mean by subduction.
- Identify which plates are involved in subduction.
- Describe what happens to the plates during subduction.
- Describe the geological features that are associated with subduction zones.

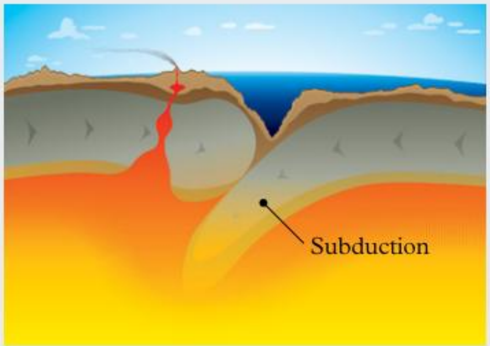


Figure 5 Subduction zone

» The Earth's crust

The lithosphere and the asthenosphere are different internal layers of the Earth.

- Define the term 'lithosphere'.
- Describe the asthenosphere.
- Describe how the two 'spheres' interact.
- Identify and describe other 'spheres' of the Earth.
- Explain how they interact with the lithosphere and the asthenosphere.

» Tsunami warnings

Seismic data is collected and shared by a variety of governments across the Asia–Pacific region.

- Describe how sensors are used to collect earthquake information.
- Describe how information about potential tsunamis is shared between the different governments.
- Describe how the information is shared with the population and the actions that may be taken as a result.

Figure 6 Tsunami warning signs run along the Pacific coastline in California.

» Magnetic striping

Magnetic striping was considered by some to be the final proof of plate tectonics.

- Explain magnetic striping.
- Identify where it exists.
- Describe how it is linked to sea-floor spreading.
- Explain what it tells us about the age of rocks and Earth's history.

Chapter checklist

Now that you have completed this chapter, reflect on your ability to do the following.

	I can do this.	I cannot do this yet.
• Define crust, mantle, core, tectonic plate and magma. • Describe the layered structure of Earth.	☐	☐ Go back to Topic 3.1 'The Earth is made of layers'. Page 48
• Define continental drift, sea-floor spreading, convection current, ridge push, slab pull, continental shelf and plate tectonics. • Describe evidence that supports the theory of plate tectonics.	☐	☐ Go back to Topic 3.2 'Forces cause tectonic plates to move'. Page 50
• Describe the interactions between plates that occur at transforming, converging and diverging boundaries. • Relate each of the types of boundaries with characteristic land formations.	☐	☐ Go back to Topic 3.3 'Boundaries between tectonic plates can be converging, diverging or transforming'. Page 52
• Describe how the Hawaiian Islands may have formed from a hot spot. • Provide examples of natural events that occur because of plate interactions. • Relate constructive and destructive boundaries with diverging and converging boundaries.	☐	☐ Go back to Topic 3.4 'Tectonic plates can be constructive or destructive'. Page 56
• Identify body waves and surface waves as the two main types of earth movements that occur during an earthquake and provide examples of each. • Provide examples of structures and materials that can be used to limit the impact of earthquakes.	☐	☐ Go back to Topic 3.5 'Science as a human endeavour: Engineering solutions in earthquake zones'. Page 60

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CHAPTER 4

ENERGY

4.1

Energy can be transferred

> Provide examples of types of energy.
> Explain how energy cannot be created or destroyed, but can be passed between objects.
> Draw and interpret energy transfer diagrams.

4.2

Potential energy is stored energy

> Define potential energy, elastic potential energy, gravitational potential energy, chemical potential energy and nuclear energy.
> Describe examples of the different forms of potential energy.

4.3

Moving objects have kinetic energy

> Define kinetic energy, electrical energy, thermal energy and sound energy.
> Provide examples of objects that use or have kinetic, electrical, thermal and sound energy.

4.4

Energy can be transformed

- Define and provide examples of energy transformation.
- Draw energy transformation diagrams.

4.5

Electricity is the movement of electric charges

- Describe how electrical energy affects an electric charge.
- Identify the key components of an electric circuit.
- Explain why circuit diagrams are used to represent circuits and draw appropriate circuit diagrams.

4.6

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

- Define cost–benefit analysis and criteria.
- Describe the roles of chemical, mechanical, electrical and civil engineers.
- Explain the key steps involved in evaluating an engineering proposal.

4.7

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

- Describe the energy transfers involved in a solar panel.
- Provide examples of solar power use in Australia.

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?

4.1 Energy can be transferred

Key ideas

- 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.

Learning intentions

By the end of this topic, you will be able to:

- provide examples of types of energy
- explain how energy cannot be created or destroyed, but can be passed between objects
- draw and interpret energy transfer diagrams.

transferred
describes energy that has moved from one object to another

For hundreds of years, scientists (and some mystics) have been developing theories about energy. While scientists like Nikola Tesla were able to control different forms of energy in the development of radios, electrical devices and X-ray photographs, mystics such as Tesla's friend Swami Vivekananda collaborated to examine the links between the mass of an object and its energy.

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.

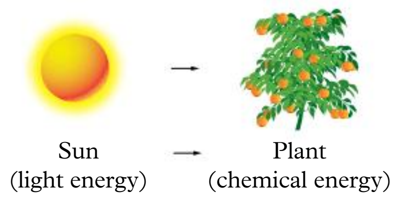


Figure 1 Plants use energy to grow.

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.

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 (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 (Figure 2).

We use the energy for moving, including walking (Figure 3). This also produces heat that then warms up the air around us (Figure 4).

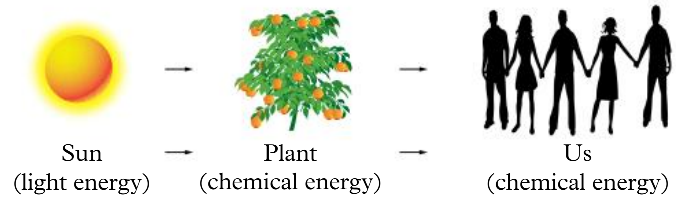


Figure 2 We use the energy from plants to move.

Figure 3 We use energy to walk and carry things.

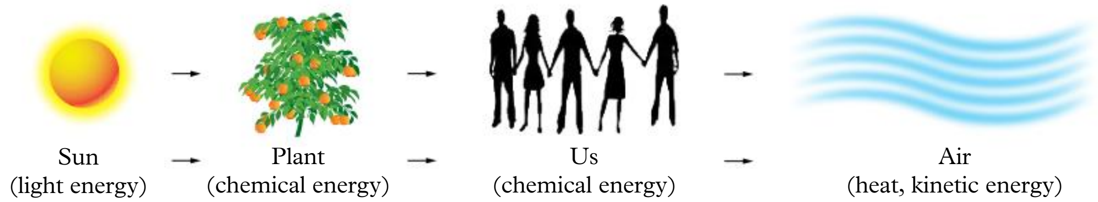


Figure 4 Heat energy warms up air.

SKILLS LAB
4.1: Draw flow diagrams of energy transfer
Go to page **187**.

Energy transfers for movement

Electric cars are 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 (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 (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 (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.

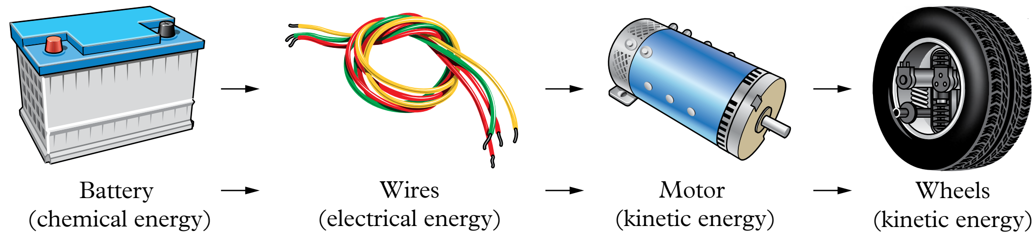


Figure 6 Chemical energy from a battery is used to turn the wheels of a car.

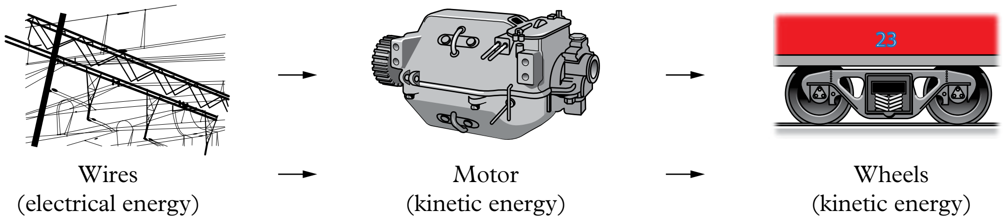


Figure 7 Electrical energy from wires is used to move the wheels of some trains.

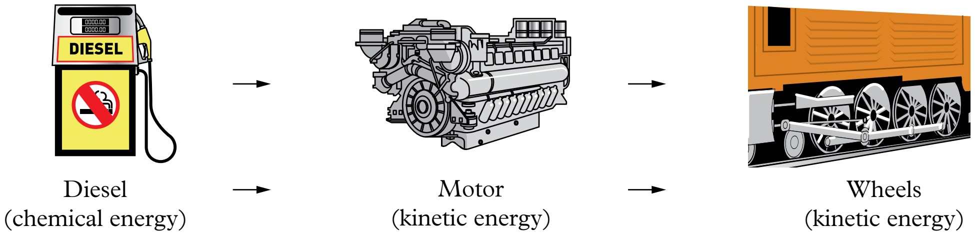


Figure 8 Chemical energy from diesel fuel is used to move the wheels of some trains.

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 (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.

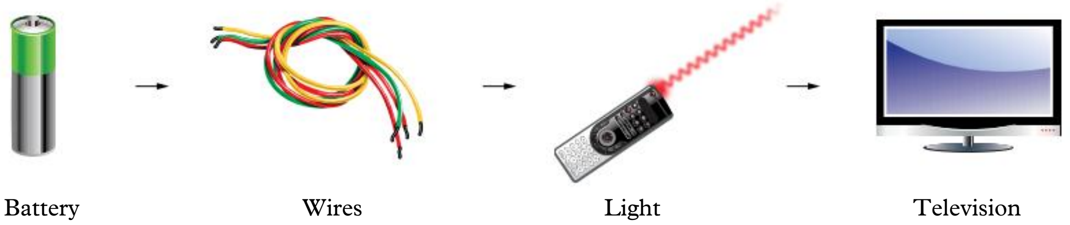


Figure 15 Television remote controls use infrared light to carry out commands.

4.1 Check your learning

Retrieve

1 **Define** the term 'energy'.

Comprehend

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

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

Analyse

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

5 Recreate Figure 16 and **label** each stage in the flow diagram.

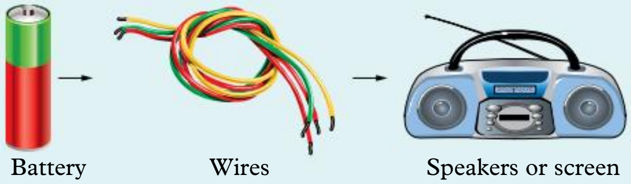


Figure 16 Flow diagram

Apply

6 **Determine** the ultimate source of all energy.

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

Quiz me

Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

4.2 Potential energy is stored energy

Learning intentions

By the end of this topic, you will be able to:

- define potential energy, elastic potential energy, gravitational potential energy, chemical potential energy and nuclear energy
- describe examples of the different forms of potential energy.

Key ideas

- 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.

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**.

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

Gravitational potential energy

If we lift an object 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, 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 the difference is how quickly the energy can be released.

Figure 3 Energy drinks contain chemical potential energy.

EXPERIMENT

4.2: What if the amount of elastic potential energy was increased?
Go to page **189**.

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.

4.2 Check your learning

Retrieve

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

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

3 **Recall** 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.

Analyse

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

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

Quiz me
Complete the Quiz me to check how well you’ve mastered the learning intentions and to be assigned a worksheet at your level.

4.3 Moving objects have kinetic energy

Learning intentions

By the end of this topic, you will be able to:

- define kinetic energy, electrical energy, thermal energy and sound energy
- provide examples of objects that use or have kinetic, electrical, thermal and sound energy.

Key ideas

- 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.

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.

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

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 (Figure 1). 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, the Sun (Figure 2).

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

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 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 3).

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

CHALLENGE
4.3: Exploring sound energy
Go to page **190**.

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 (Figure 4). 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 (Figure 5). Vibrations are simply tiny movements back and forth. Vibrations can occur in gases, liquids and solid things, such as speakers. 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)

Figure 5 Musical instruments use kinetic energy to produce sound.

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

4.3 Check your learning

Retrieve

1 **Recall** the scientific term for 'movement energy'.
2 **Identify** what is moving in electrical energy.
3 **Identify** what is moving when a guitar produces sound energy.
4 **Recall** another name for heat energy.

Comprehend

5 **Describe** how solar cells are used in the transfer of energy.

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.

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

4.4

Energy can be transformed

Learning intentions

By the end of this topic, you will be able to:

- define and provide examples of energy transformation
- draw energy transformation diagrams.

Key ideas

- 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.

Interactive 4.4
Energy transformations

transformed describes energy that has changed into a different form

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

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 (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.

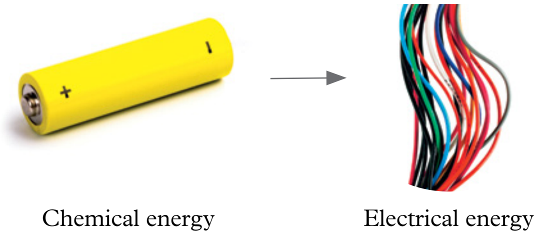


Figure 2 A flow diagram showing how a battery transforms chemical energy into electrical energy.

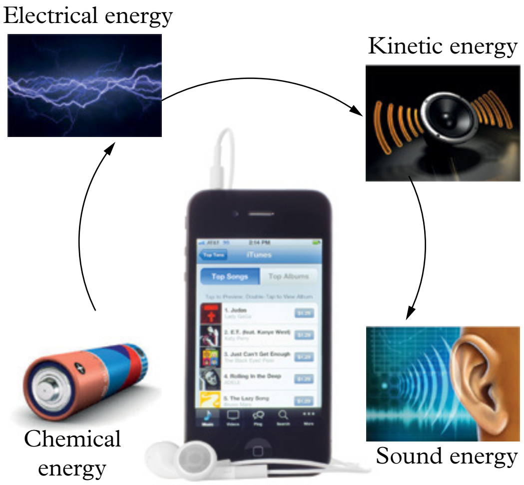


Figure 3 Chemical energy in the mobile device battery is transformed into the sound energy that we hear.

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.'

Figure 3 shows this energy story as a flow diagram.

Generating electricity

There are many ways to generate electricity. Different 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 (Figure 4).

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.

CHALLENGE
4.4: Energy converters
Go to page **191**.

Pipes control the flow of water down through the turbine, transforming the gravitational potential energy into the kinetic energy of the turbines (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 (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

4.4 Check your learning

Retrieve

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

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

Analyse

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

Apply

4 **Create** a flow diagram for the main energy transformations in a moving car.

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

6 For each of the electricity generators above, **create** a flow diagram of the energy transformations.

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

4.5 Electricity is the movement of electric charges

Learning intentions

By the end of this topic, you will be able to:

- describe how electrical energy affects an electric charge
- identify the key components of an electric circuit
- explain why circuit diagrams are used to represent circuits and draw appropriate circuit diagrams.

Key ideas

- A closed circuit occurs when the positive and negative charges can be separated and reunited.
- A conductor allows the charges to flow easily.
- An insulator restricts the movement of the charges.
- An electric circuit contains an energy source (a battery), a pathway (usually wires) and a load.
- The pathway of the charges can be represented by a circuit diagram.

electric circuit	a closed pathway that conducts electrons in the form of electrical energy
electric current	the flow of electrical charge through a circuit
circuit diagram	a diagrammatic way to represent an electric circuit
positive terminal	the point in an electric circuit where electrons flow into
negative terminal	the point in the circuit where electrons flow out from

Electrical energy and circuits

'Electricity' is a kinetic energy term for the presence and movement of charged particles. An electric charge can be either positively or negatively charged. When electric charges become separated, they have electrical energy. This means they are in a state of excitement and the positive and negative charges try to get back together again. They can do this along a metal wire in a circuit. If the wires are connected in a loop (closed circuit), the negative charges will move along the wire to the positive charges. As the charges move, the electrical kinetic energy may transform into some other forms of energy, such as light or thermal energy.

A closed conducting pathway is called an **electric circuit**. As electrically charged particles move around an electric circuit, they carry energy from the energy source (such as a battery) to the device that transforms the energy (such as a light globe, motor or heater). An example of the movement of electrical energy in a simple circuit is shown in Figure 1.

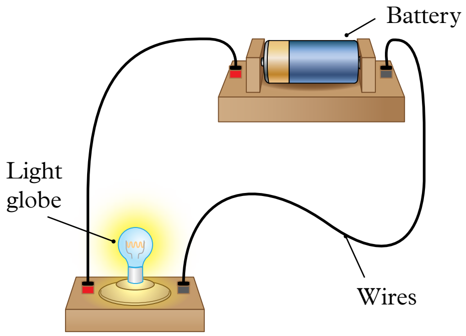


Figure 1 A simple circuit: electric charges move from the battery through the wires to the light globe.

Electric circuits

The pathway travelled by electrical energy is called an electric circuit. Electric circuits must have an energy source, wires to carry the charges, and a 'load', which is any device that converts the electrical energy into heat, light or kinetic energy. Many devices have 'gaps' called switches to control the flow of electricity in a circuit.

Moving charges

An **electric current** occurs when negatively charged particles move through an electric circuit. These particles move, or are conducted, from the negative terminal of the energy source to the positive terminal. This is different to the historical term 'conventional current' (where the direction of the current is described as moving from the positive terminal to the negative terminal; Figure 2).

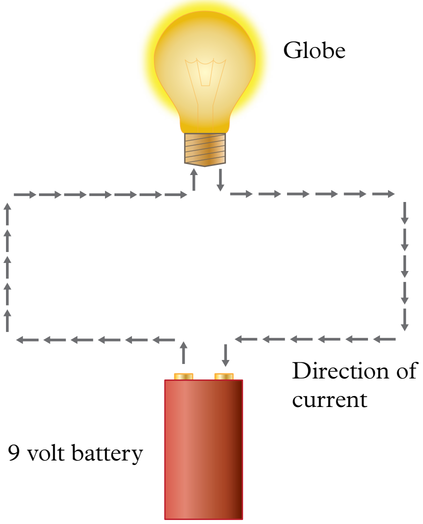


Figure 2 Conventional current in an electric circuit

CHALLENGE
4.5: Making a simple torch circuit
Go to page **192**.

There are two types of current used in electrical circuits. In an alternating current (AC), the flow of electrons reverses direction 50 times every second. This type of current is used in electrical power points. In direct current (DC), the electrons flow in one direction only. This current is found in battery-powered circuits.

Circuit diagrams

Circuits are represented by **circuit diagrams**. Each component of a circuit is represented by a symbol (Figure 3). The circuit illustrated in Figure 4a includes a globe, a battery, connecting wires, a switch and a meter, such as an ammeter, to measure the electric current. This circuit is represented by the circuit diagram in Figure 4b. Connecting wires are usually shown as straight lines, and when they meet at junctions they are often (but not always) joined at right angles. The longer line on the battery represents the **positive terminal** and the shorter line represents the **negative terminal**. These terminals are where the wires are connected. When drawing a circuit diagram, you should use a ruler and a pencil. All lines should be connected to indicate that there are no breaks in the circuit. A break in the circuit means the current is not flowing.

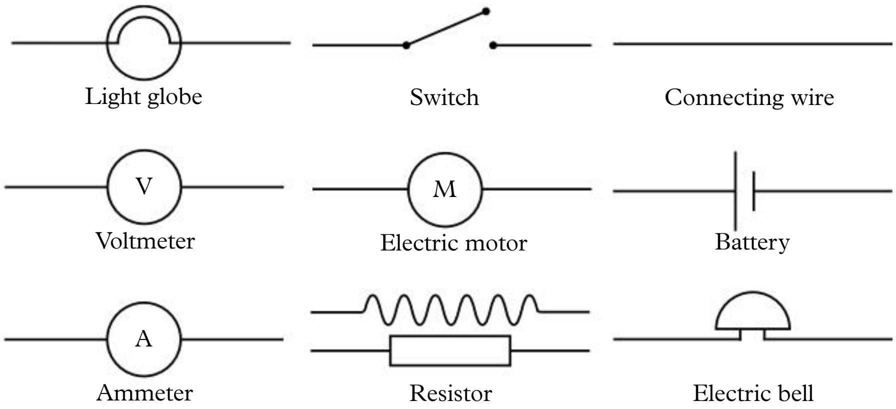


Figure 3 Some symbols used in circuit diagrams

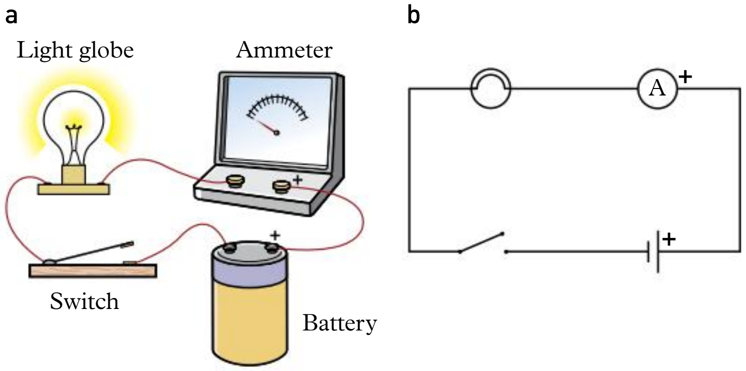


Figure 4 a A simple circuit **b** A circuit diagram of the simple circuit

4.5 Check your learning

Retrieve

1 **Identify** the direction of:
   a a conventional current
   b electrons in a circuit.

2 **Identify** the energy transformation that occurs in a battery in a circuit.

Comprehend

3 **Identify** and **describe** the role of each of the parts of the circuit in Figure 4.

4 **Describe** how you could stop the charged particles flowing in a circuit.

Analyse

5 **Contrast** (the differences between) AC and DC.

6 **Compare** (the similarities and differences between) the equipment and drawings used in Figure 1 and Figure 4b.

7 **Identify** which of the globes in Figure 5 will transform electrical energy into light energy.

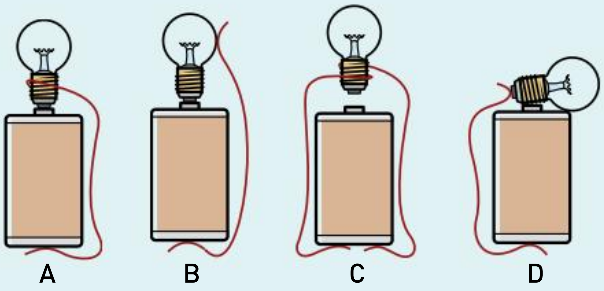


Figure 5 Light globes

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

4.6

Engineers use their understanding of energy to solve problems

Learning intentions

By the end of this topic, you will be able to:

- define cost–benefit analysis and criteria
- describe the roles of chemical, mechanical, electrical and civil engineers
- explain the key steps involved in evaluating an engineering proposal.

motion
when an object changes its position over time

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.

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 (Figure 1). 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 2)!

Figure 2 Yo-yos are fun toys that use mechanics to work.

Figure 1 Water slides transform the gravitational potential energy of the water into kinetic energy. Reducing the friction of the slide makes it more efficient.

CHALLENGE

4.6A: Leakywater Council swimming pool and waterslide Go to page 193.

EXPERIMENT

4.6B: Investigating structures and materials using icy pole sticks Go to page 195.

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 and 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.

4.6 Test your skills and capabilities

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.

1 **Social impact assessment** – **Explain** whether the project will have a good or bad impact on people's lives.

2 **Risk assessment** – **Describe** what might happen if the project fails.

3 **Environmental impact** – **Describe** the effects the eel traps will have on the environment.

4 **Contamination assessment** – **Identify** whether any chemicals used in the project will contaminate living things.

5 **Strength and facility life assessment** – **Describe** the loads the structure will need to withstand. **Describe** how long the structures will survive.

6 **Geotechnical hazard assessment** – **Describe** any problems that might be experienced with digging the soil.

//SCIENCE AS A HUMAN ENDEAVOUR//

4.7

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

Learning intentions

By the end of this topic, you will be able to:

- describe the energy transfers involved in a solar panel
- provide examples of solar power use in Australia.

Video 4.7A
Ask a scientist – Dr Niraj Lal (Physicist)

Video 4.7B
Solar panel roads in France

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 to power heating and cooling devices is growing rapidly every year.

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 the Sun shines 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 (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 that the light energy 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 (Figure 2).

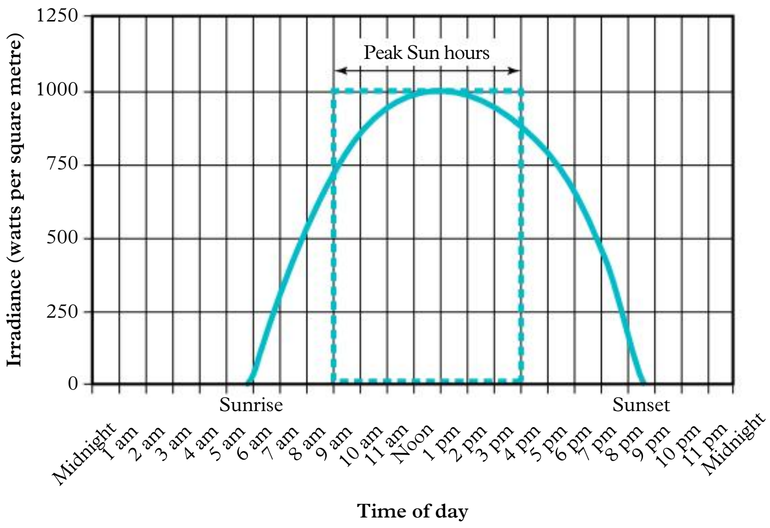


Figure 1 A graph showing the peak Sun hours over a day

CHALLENGE

4.7: The Sun's energy
Go to page **196**.

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

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.

Alternatives to fossil fuel cars

Since the beginning of the 1900s, people have relied on cars to move from one place to the next. These cars rely on the chemical energy in fossil fuels (petrol and diesel) to generate the kinetic energy to move. This energy transformation from chemical energy to movement energy has contributed to the generation of carbon dioxide that is warming the atmosphere. As a result, modern scientists and engineers are working to develop alternative forms of energy transformation.

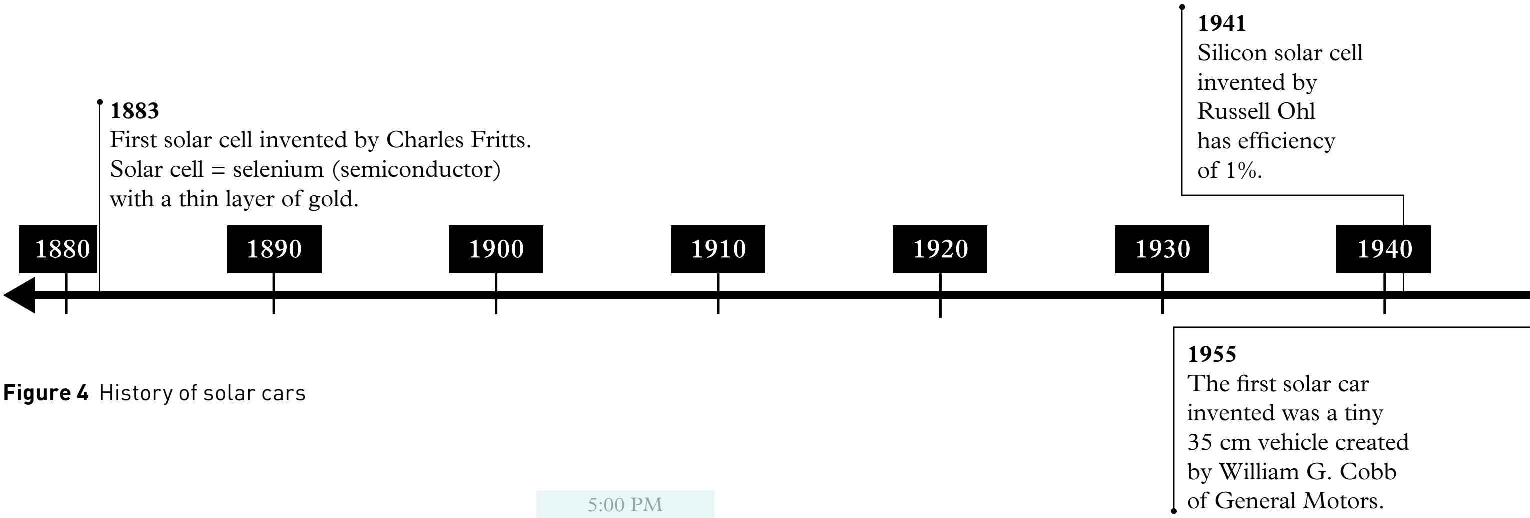
Hybrid cars combine combustion engines that use fossil fuels with electric engines that use energy stored when the car brakes, or any extra energy that is not used by the combustion engine. These cars cannot be plugged into the energy grid to charge the battery.

Electric cars use the chemical energy in batteries to generate kinetic energy. The batteries can be charged through the same electrical grid that powers your house. They can also use solar panels to transform sunlight into electrical energy, which can be stored as chemical potential energy in the battery.

Solar cars use a variety of solar panels to transform light energy into kinetic energy. Most current solar-powered vehicles only carry one person (Figure 3). 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.

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

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

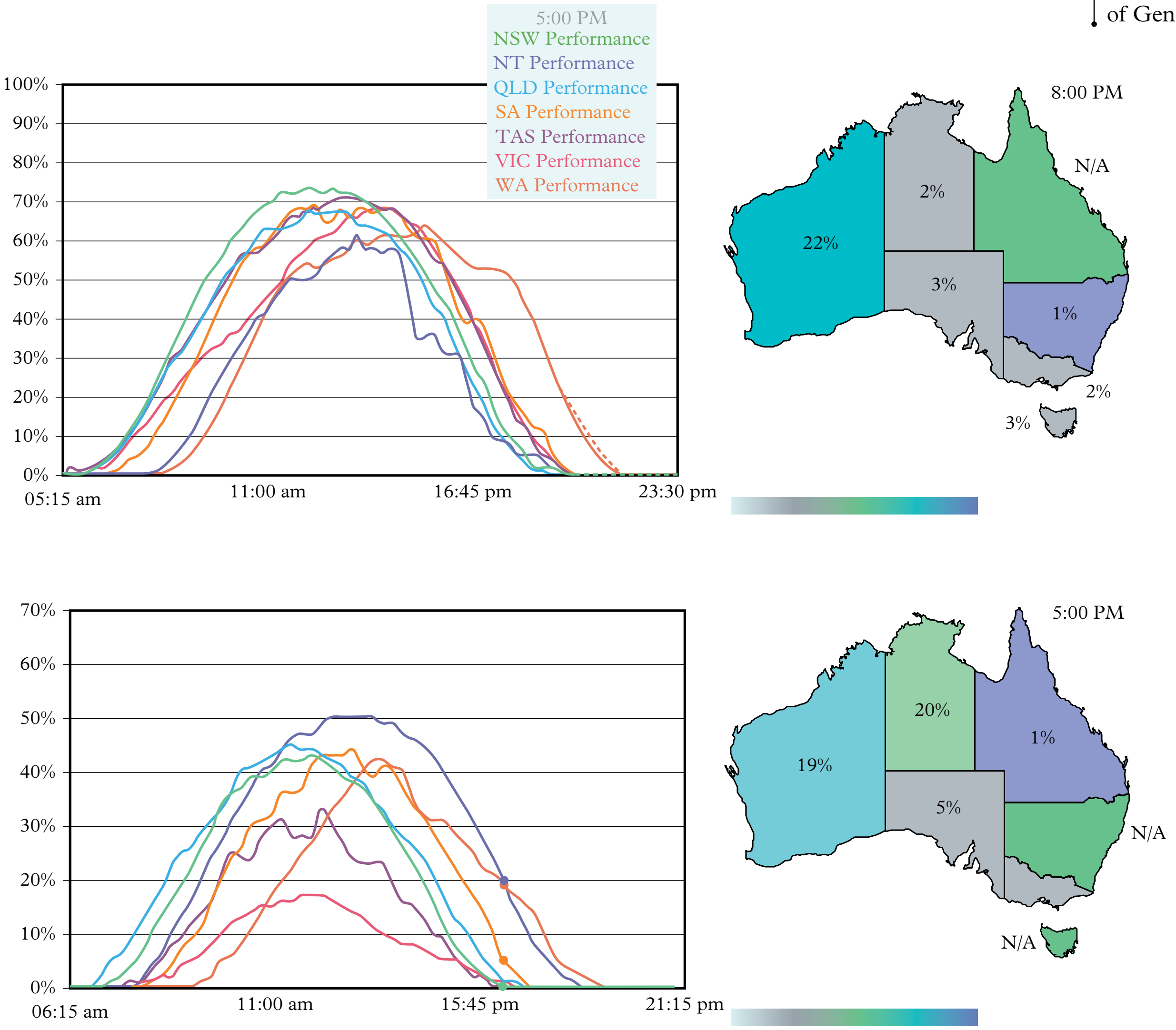


Figure 5 Estimated photovoltaic output as a percentage of its maximum capacity in each state at different times of the year

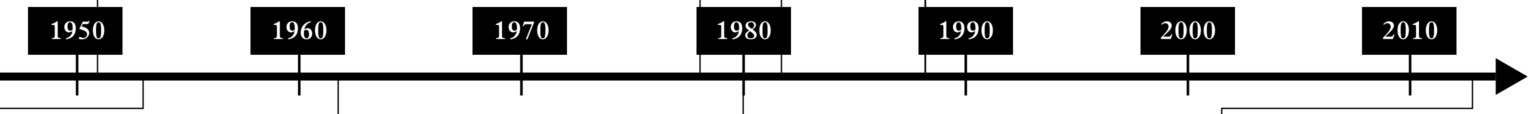


Figure 6 A 1970s electric CitiCar

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'.

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.

4.7 Test your skills and capabilities

Analysing graphs

The amount of (photovoltaic) sunshine available across Australia changes according to the time of the year (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** Queensland'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 Queensland.
  - **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.

CHAPTER 4 REVIEW

ENERGY

Retrieve

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** which of the following correctly describes the energy transformation in a simple electrical circuit containing a battery and a light.
   - **A** battery → wires → light
   - **B** battery → light → wire
   - **C** electrical energy → light energy
   - **D** chemical energy → electrical energy → light energy

4 **Identify** which of the following is true or false. Rewrite any false statements 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.

5 **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

6 **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.

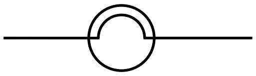
7 **Recall** the type of energy musical instruments use to produce sound.

Figure 1 Musical instruments use energy to produce sound.

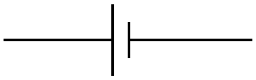
8 **Select** a name from the list below and **label** the circuit symbols shown in parts a–d.

ammeter, battery, globe, switch

a

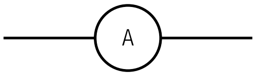


b



c

d



Comprehend

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

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

11 **Explain** why heat is generated in a light bulb.

12 **Describe** the energy transformation and energy transfer in a torch.

Analyse

13 **Contrast** the number of energy transfers in the generation of electricity in solar panels and hydroelectricity.

14 **Compare** the energy transformation when electricity is generated by coal and water.

15 **Connect** 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

16 **Contrast** the terms ‘transform’ and ‘transfer’.

17 **Compare** potential energy and kinetic energy.

18 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.

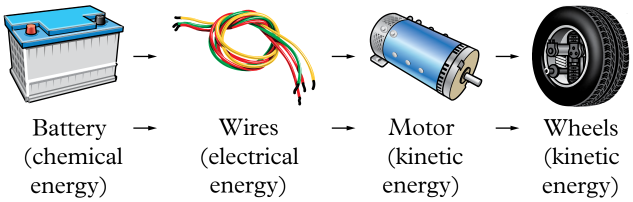


Figure 2 A car produces kinetic energy in its wheels.

19 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. **Consider** which energy form was the most common and why.

Apply

20 Visit a local playground and **consider** the play equipment. Take a photo or draw a picture of a piece of equipment and **determine** what types of energy are demonstrated as a child plays on the equipment.

21 **Create** a flow diagram that demonstrates the flow of energy involved in riding a bike. (HINT: Start with the Sun!)

Figure 3 Pedal power

22 **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).

23 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, **determine** 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

24 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 another 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

25 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 First Nations peoples’ rights and interests, though most First Nations peoples have little to no legal input during the planning stages for these projects. **Evaluate** the importance of consulting the Traditional Custodians of the land you are working on or changing.

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

27 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

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.

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.

Figure 4 The CFL in this image is turned on.

Energy-efficient housing

In previous times, energy efficiency was important because people had limited access to energy supplies 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.
- Describe three ways modern humans can be energy efficient today.
- Compare the advantages and disadvantages of each energy-efficiency method used in the past and present.

New and specialised engineering fields

Engineers use science, technology and mathematics to solve problems. Select one of the newer fields of engineering, such as 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 that an engineer in the field has worked on.

Figure 5 Aerospace engineers at work.

Rube Goldberg machine

Rube Goldberg was an American cartoonist who drew a series of complex machines that used a series of energy transfers and transformations to perform a simple task (Figure 6).

- Design your own Rube Goldberg machine by selecting a simple task that you do most days.
- Draw a picture that shows how this task could become more complex using a series of energy transformations and transfers.
- Identify each energy transfer and transformation that occurs in your machine.

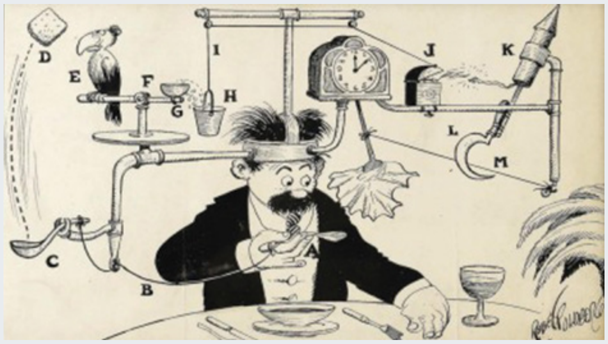


Figure 6 A Rube Goldberg cartoon

Chapter checklist

Now that you have completed this chapter, reflect on your ability to do the following.

	I can do this.	I cannot do this yet.
• Provide examples of types of energy. • Explain how energy cannot be created or destroyed, but can be passed between objects. • Draw and interpret energy transfer diagrams.	☐	☐ Go back to Topic 4.1 'Energy can be transferred'. Page 70
• Define potential energy, elastic potential energy, gravitational potential energy, chemical potential energy and nuclear energy. • Describe examples of the different forms of potential energy.	☐	☐ Go back to Topic 4.2 'Potential energy is stored energy'. Page 74
• 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 4.3 'Moving objects have kinetic energy'. Page 76
• Define and provide examples of energy transformation. • Draw energy transformation diagrams.	☐	☐ Go back to Topic 4.4 'Energy can be transformed'. Page 78
• Describe how electrical energy affects an electric charge. • Identify the key components of an electric circuit. • Explain why circuit diagrams are used to represent circuits and draw appropriate circuit diagrams.	☐	☐ Go back to Topic 4.5 'Electricity is the movement of electric charges'. Page 80
• Define cost–benefit analysis and criteria. • Describe the roles of chemical, mechanical, electrical and civil engineers. • Explain the key steps involved in evaluating an engineering proposal.	☐	☐ Go back to Topic 4.6 'Science as a human endeavour: Engineers use their understanding of energy to solve problems'. Page 82
• Describe the energy transfers involved in a solar panel. • Provide examples of solar power use in Australia.	☐	☐ Go back to Topic 4.7 'Science as a human endeavour: Solar cells transform the Sun's light energy into electrical energy'. Page 84

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Quizlet
Play a Quizlet game to test your knowledge.

Chapter quiz
Test your understanding of this chapter with the chapter review quiz.

CHAPTER

5

PHYSICAL AND CHEMICAL CHANGE

5.1

All matter is made up of atoms

- Describe the development of atomic theory over time.
- Identify the main scientists who contributed to the development of the periodic table.

5.2

Elements are made up of one type of atom

- Define and describe the key features of the periodic table including periods, groups, elements, monatomic gases and diatomic gases.
- Describe the relationship between an element's atomic number and atomic mass, and its subatomic particles.

5.3

Atoms bond together to make molecules and compounds

- 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.

5.4

Matter can be modelled

- Describe how elements, compounds, molecules and mixtures can be modelled.
- Contrast suspensions and colloids.

5.5

Physical change is a change in shape or appearance

- Define vaporise, vapour, fumes, volatile, boiling, condense, melt and sublimation.
- Describe the processes involved in each change of state.

5.6

Chemical change produces new substances

- Explain the difference between chemical and physical changes and provide examples of each.
- Identify the features of a chemical change.

5.7

Chemical reactions can break bonds and re-form new bonds

- Identify the reactants and products in a chemical reaction.
- Describe the purpose of chemical equations.

5.8

Chemical reactions can be sped up and slowed down

- Define collision theory, concentration, catalyst and enzyme.
- Explain factors that increase the rate of a reaction.

5.9

Science as a human endeavour: Many substances exist because of the work of scientists

- Describe how chemical reactions are used in everyday life.
- Provide examples of everyday experiments.

5.10

Science as a human endeavour: Physical and chemical changes are used to recycle household waste

- Classify the processes involved in recycling plastic as physical or chemical changes.
- Explain the benefits of recycling.

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?

5.1 All matter is made up of atoms

Learning intentions

By the end of this topic, you will be able to:

- describe the development of atomic theory over time
- identify the main scientists who contributed to the development of the periodic table.

Key ideas

- All matter is made up of atoms.
- Scientists refine models over time.

Figure 1 Antoine Lavoisier and his wife, Marie-Anne, were convinced that matter could not be created or destroyed.

atomic theory the theory that all matter is made up of atoms

What are atoms?

In Year 7 you learnt about the ideas of Democritus and the Ancient Greeks. They used the word *atomos* to describe those particles that could not be divided up any further. The concept of the atom was also described in ancient Indian texts over 2000 years ago. Although we cannot see atoms, there is much evidence that this basic form of matter exists.

In around 450 BCE, the Greek philosopher Democritus said:

> By convention there is colour, by convention sweetness, by convention bitterness, but in reality there are atoms and the void.

Democritus was a natural philosopher. He did not carry out experiments, but proposed hypotheses based on thought and reasoning. Over the next 1500 years, scientists tried many experiments to detect these invisible particles that make up all life on Earth.

By the 1780s, French chemist Antoine Lavoisier and his wife Marie-Anne Lavoisier were convinced that matter could not be created or destroyed. Like many scientists of the time, they were interested in the study of mixtures in 'invisible' air. They used a series of tests to divide the different 'atoms' into metals and non-metals.

English scientist John Dalton was fascinated by this research and in 1810 he stated:

> Matter, though divisible in an extreme degree, is nevertheless not infinitely divisible. That is, there must be some point beyond which we cannot go in the division of matter ... I have chosen the word 'atom' to signify these ultimate particles.

Dalton was one of the first scientists to consider the link between elements and atoms. He was the originator of what is now called the **atomic theory**.

Dalton's atomic theory

One of the pieces of evidence that Dalton published was that all atoms had different weights. Although the weight of an atom is too small to measure, Dalton was able to compare the weight of the lightest atom (hydrogen) to all of the other atoms that were then known. He assigned comparison weights to atoms such as oxygen, carbon and nitrogen, using the results of chemical analysis carried out by other chemists.

Evidence supports atomic theory

A scientific theory aims to explain existing evidence and observations. A good theory supported by evidence can be used to make testable predictions. Ever since Dalton proposed his atomic theory, it has been used to make predictions, and evidence that was not available in Dalton's time supports his theory.

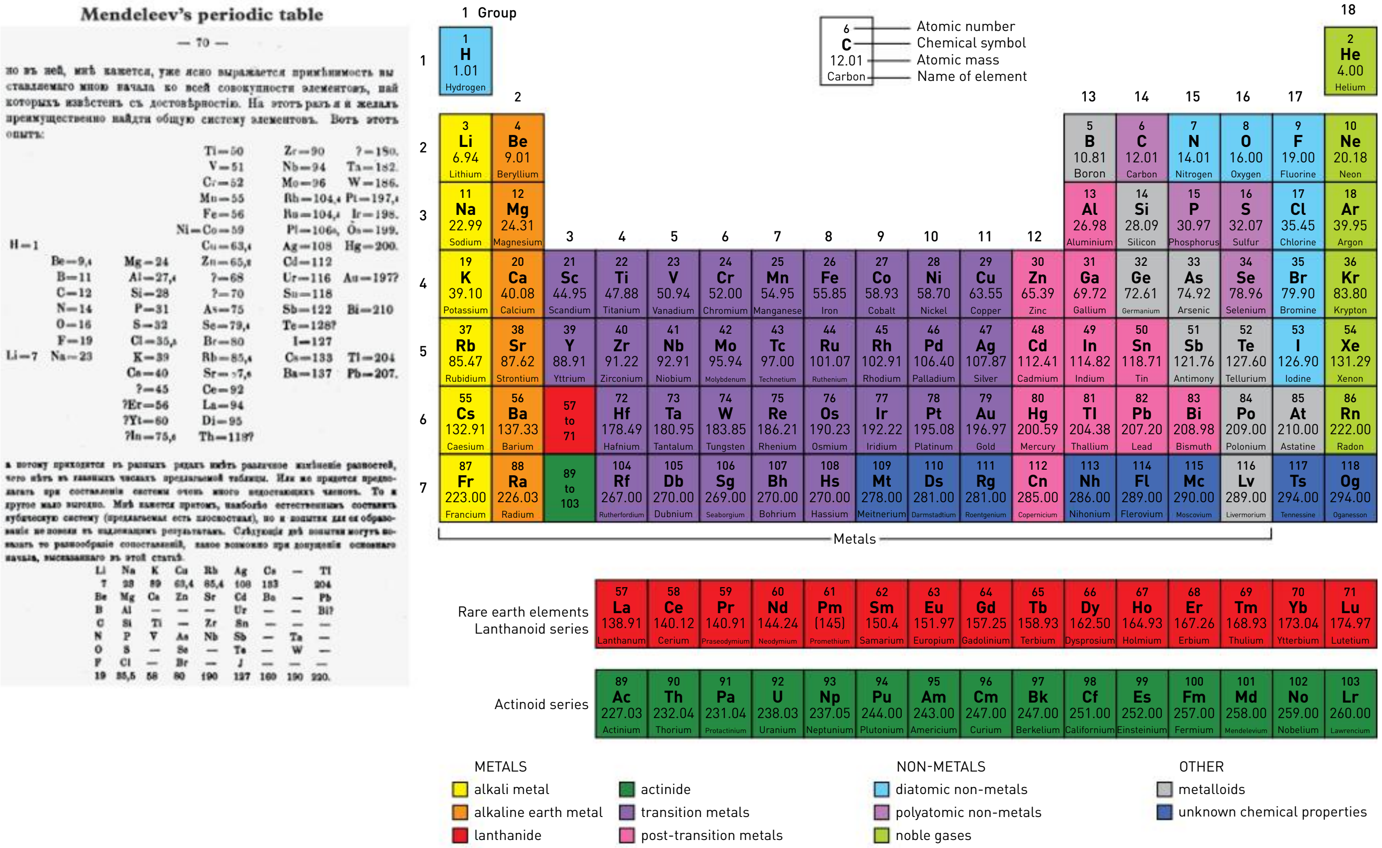
- Elements can join together to form new substances.
- Water always contains twice as much hydrogen as oxygen.
- When chemicals react with each other, the total mass of the chemicals does not change.
- Pure oxygen has the same properties wherever it is found on the Earth or even in space.
- Gases, some of which are invisible, have mass and different gases have different masses.
- Modern scanning tunnelling microscopes produce images of surfaces that look 'bumpy'.
- Under a microscope, tiny particles of pollen in water move in strange ways as if bumping into invisible objects.

CHALLENGE
5.1: Classifying atoms according to their properties
Go to page 197.

Mendeleev organises atoms

By 1869, up to 56 atoms had been discovered by chemists around the world. In 1865, British scientist John Newlands published a paper that described how these atoms could be arranged into groups of eight atoms with similar properties. He called this the Law of Octaves. While many scientists did not agree at the time, Russian scientist Dmitri Mendeleev was preparing a textbook for his university students when he dreamed of patterns of atomic properties. When he woke up, he drew the pattern of atoms in a table. This table was so accurate, he was able to predict the properties of atoms that had not yet been discovered. This table became known as the **periodic table**. The periodic table we use today identifies the many different properties of every atom that has been discovered or created so far.

periodic table
a table in which elements are listed in order of their atomic number, and grouped according to their similar properties



Mendeleev's periodic table

6
C
12.01
Carbon

Atomic number
Chemical symbol
Atomic mass
Name of element

	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 Tl 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

Metals

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

METALS
- 🟨 alkali metal
- 🟧 alkaline earth metal
- 🟥 lanthanide
- 🟩 actinide
- 🟪 transition metals
- ■ post-transition metals

NON-METALS
- 🟦 diatomic non-metals
- ■ polyatomic non-metals
- ■ noble gases

OTHER
- ⬜ metalloids
- 🟦 unknown chemical properties

Figure 2 There are some similarities between Mendeleev's periodic table and the periodic table we currently use.

5.1 Check your learning

Comprehend

1 **Summarise** the discoveries made by the following scientists.
   - **a** John Dalton
   - **b** Antoine and Marie-Anne Lavoisier
   - **c** John Newlands
   - **d** Dmitri Mendeleev

2 **Describe** why the periodic table is useful for scientists and chemists today.

Analyse

3 **Compare** (the similarities and differences between) a philosopher such as Democritus and a scientist such as John Dalton.

4 **Compare** (the similarities and differences between) Mendeleev's periodic table and the periodic table currently used by scientists (Figure 2).

Apply

5 **Create** a timeline that shows the development of atomic theory through to the development of the periodic table.

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

5.2 Elements are made up of one type of atom

Learning intentions

By the end of this topic, you will be able to:

- define and describe the key features of the periodic table including periods, groups, elements, monatomic gases and diatomic gases
- describe the relationship between an element's atomic number and atomic mass, and its subatomic particles.

Key ideas

- An element is a pure substance with one type of atom.
- The periodic table organises elements according to their chemical and physical properties.

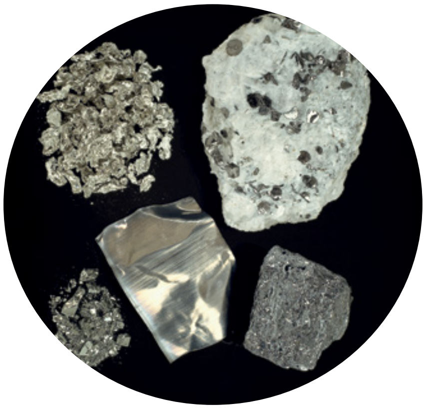


Figure 1 Not all metals are the same.

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 94–98 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 reactive 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 (Figure 2). 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) (Figure 3). 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**. 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.

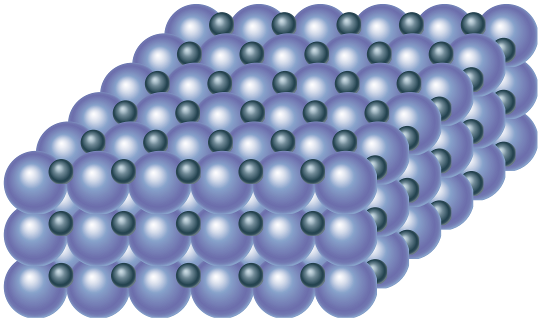


Figure 2 A metallic lattice

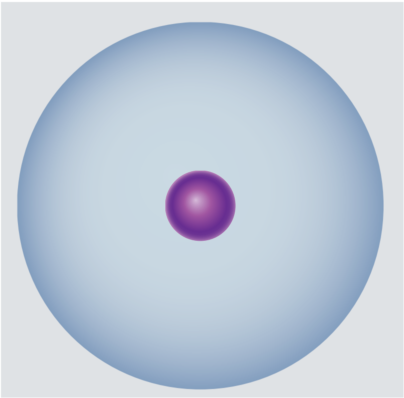


Figure 3 Helium is monatomic.

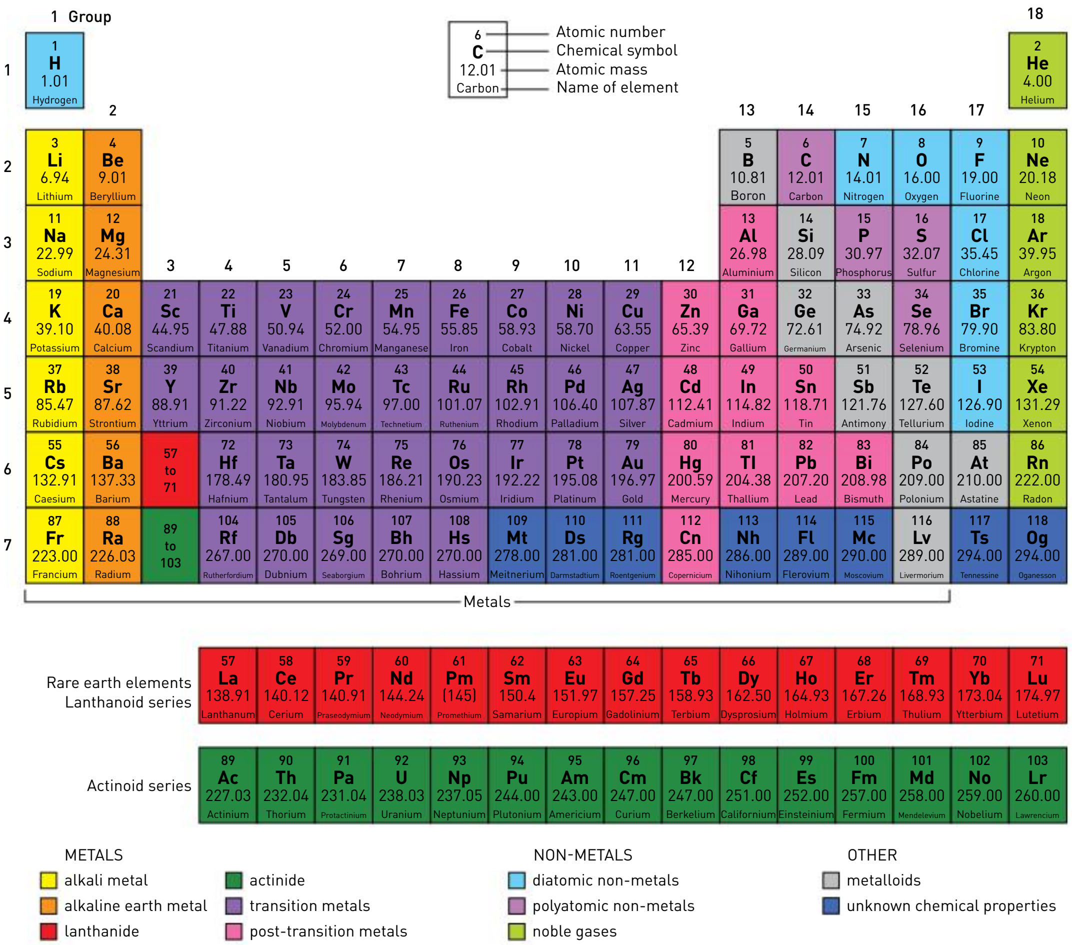
atom	the smallest particle of matter; cannot be created, destroyed or broken down (indivisible)
monatomic	consisting of a single atom
diatomic molecule	a molecule that consists of two atoms
period	(in chemistry) a horizontal list of elements in the periodic table
group	(in chemistry) a vertical list of elements in the periodic table that have characteristics in common

CHALLENGE

5.2A: Identifying the elements in the periodic table
Go to page **198**.

EXPERIMENT

5.2B: Properties of the elements
Go to page **199**.



6
C
12.01
Carbon

- Atomic number
- Chemical symbol
- Atomic mass
- Name of element

	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
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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 **Tl** 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

Metals

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

METALS
- 🟨 alkali metal
- 🟧 alkaline earth metal
- 🟥 lanthanide
- 🟩 actinide
- 🟪 transition metals
- ☐ post-transition metals

NON-METALS
- ☐ diatomic non-metals
- ☐ polyatomic non-metals
- ☐ noble gases

OTHER
- ☐ metalloids
- 🟦 unknown chemical properties

Figure 4 The periodic table

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).

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.

5.2 Check your learning

Retrieve

1 **Identify** the two large groups in the periodic table.

2 **Recall** the name given to the rows of the periodic table.

3 **Identify** the names and symbols of the first five elements in the periodic table.

Analyse

4 **Identify** the element found in period 3, group 2.

5 **Identify** the two letters that are not represented in the elemental symbols of the periodic table.

6 **Compare** (the similarities and differences between) atoms and elements.

Apply

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.)

Quiz me

Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

5.3 Atoms bond together to make molecules and compounds

Learning intentions

By the end of this topic, you will be able to:

- 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.

Key ideas

- 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.

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 (Figure 1). 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.

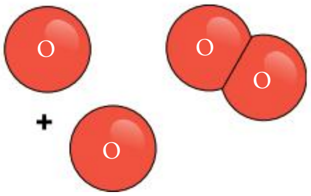


Figure 1 Oxygen (O_2) is a molecular element formed by two oxygen atoms.

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) (Figure 2). Pure carbon dioxide gas (the substance) consists of millions and millions of carbon dioxide molecules.

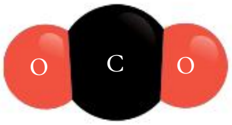


Figure 2 Carbon dioxide (CO_2) is a molecular compound made up of one carbon atom and two oxygen atoms.

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 (Figure 3). 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.

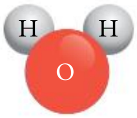


Figure 3 Water (H_2O) is a molecular compound made up of two hydrogen atoms and one oxygen atom.

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 4 shows the difference between compounds and mixtures.

Interactive 5.3
Elements and compounds

Video 5.3
Elements and compounds

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)

EXPERIMENT

5.3: Decomposing copper carbonate
Go to page **200**.

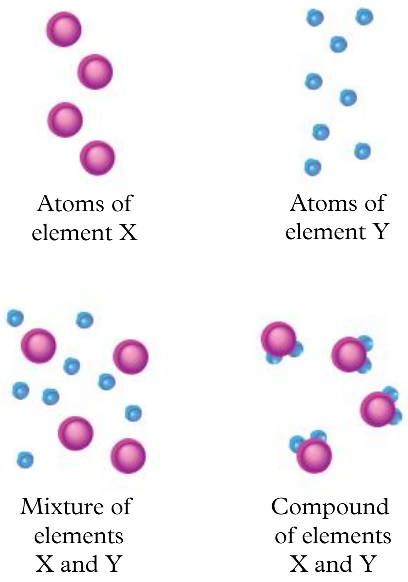

Atoms of element X
Atoms of element Y
Mixture of elements X and Y
Compound of elements X and Y

Figure 4 Mixtures are different from compounds.

Compounds

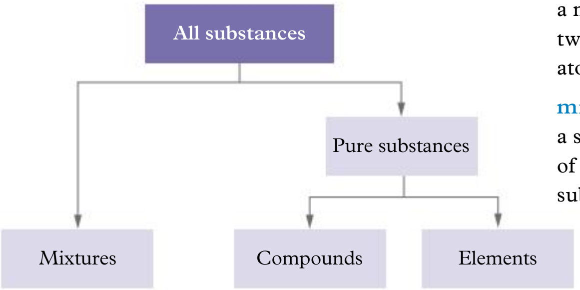
You have seen that elements contain only one type of atom. However, there are far more substances than just the 94–98 naturally occurring elements.

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 5 shows the different types of substances.



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

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)

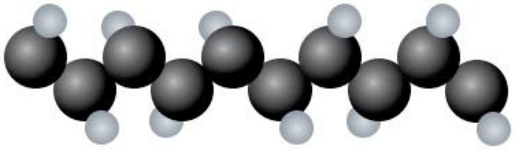


Figure 5 A polyethylene molecule is made up of thousands of carbon atoms joined in a chain, with hydrogen atoms attached to the carbon chain. It is a polymer.

5.3 Check your learning

Retrieve

1 **Identify** two elements that exist as molecules rather than single atoms.

Analyse

2 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.

3 **Compare** (the similarities and differences between) molecules and compounds.

4 **Contrast** (the differences between) the following terms:
- **a** atom and molecule
- **b** element and compound
- **c** compound and mixture
- **d** molecule, polymer and lattice.

Apply

5 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.

Quiz me
Complete the Quiz me to check how well you’ve mastered the learning intentions and to be assigned a worksheet at your level.

5.4 Matter can be modelled

Learning intentions

By the end of this topic, you will be able to:

- describe how elements, compounds, molecules and mixtures can be modelled
- contrast suspensions and colloids.

Key ideas

- Elements are represented by symbols.
- Compounds and molecules are represented by formulas.
- Mixtures are represented by percentages.

For hundreds of years, many scientists refused to believe that matter was made up of atoms. This was because the atoms were too small to be seen. It wasn't until scientists were able to model what an atom looked like, and how they joined together to form a compound, that scientists were able to explain the different properties of chemicals and mixtures.

Most models used today do not show exactly what molecules look like, but they are useful tools to explain the structure and shapes of groups of atoms.

Representing elements

The development of the periodic table by Mendeleev and other chemists allows us to identify the different elements that make up the world around us. Each element has a unique chemical symbol that can be used to identify the type of atom. For example, the element oxygen is represented by the letter O, while hydrogen is represented by the letter H. Some elements are represented by two letters. When this occurs, the first letter is a capital letter, while the second letter is a lowercase letter. For example, helium is represented by He. When modelling atoms, all elements are usually represented by a single ball shape (Figure 1).

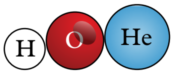


Figure 1 Element atoms are represented by a single ball shape.

Chemical formulas

When atoms join or bond together, they form molecules. An example of this is the molecule water (H_2O). The small number two after the H describes the number of hydrogen atoms that are in the water molecule. If there is no number after the letter, then it means there is only one of that atom present. For example, each water molecule (H_2O) will always have two atoms of hydrogen and one atom of oxygen. This formula for water remains the same if the water is a solid (ice), liquid or gas (water vapour).

If the ratio of hydrogen and oxygen atoms changes (H_2O_2) then the compound becomes a new chemical (hydrogen peroxide).

Chemical formulas are also used to show when two atoms join together to form a molecular element. For example, oxygen rarely exists as a single atom. Instead, it joins with another oxygen atom to form O_2.

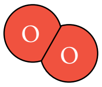


Figure 2 An oxygen molecule is made up of two oxygen atoms.

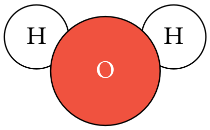


Figure 3 A water molecule is made up of one oxygen atom and two hydrogen atoms.

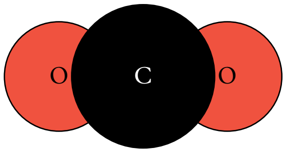


Figure 4 Carbon dioxide is made up of one carbon atom and two oxygen atoms.

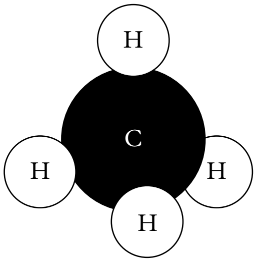


Figure 5 Methane is made up of one carbon atom and four hydrogen atoms.

When modelling atoms, it can sometimes be difficult to label individual atoms. For this reason, scientists usually have a colour code to identify the different atoms (Table 1).

CHALLENGE

5.4: Modelling elements, molecules and compounds
Go to page **201.**

Table 1 Different colours are used to represent different types of atoms in a model.

Element	Atom colour
Carbon	Black
Hydrogen	White
Oxygen	Red
Nitrogen	Blue
Fluorine	Yellowish green
Chlorine	Light green
Sulfur	Yellow
Phosphorus	Purple

Mixtures

When two different molecules are mixed together, it can become difficult to use symbols to tell the two types of molecules apart. For example, when water (H_2O) is mixed with sodium chloride (NaCl – table salt), we need to know how much water and table salt is present. For this reason, percentages can be used to represent the amount of each substance. An example of this is the amount of salt in the ocean, described as 35% NaCl; 65% H_2O (350 grams of NaCl salt in every litre of sea water). As you learnt in Year 7, sea water is a **solution** because the NaCl (salt solute) is mixed evenly through the water (solvent). This can be modelled by the molecules being evenly mixed together without being bonded (stuck) together.

Suspensions

Suspension mixtures usually occur when the solute particles are too large to 'hide' between the solvent particles. An example of this occurs when dirt is mixed with water. Over time, the solute can sink to the bottom of the container and become sediment. This is more difficult to model as the large solute particles need to be combined together like a solid, before being mixed with the solvent. Suspensions can also be represented using percentages (25% dirt in water).

Figure 6 A good example of a suspension is dirt mixed with water.

Colloids

Colloids occur when two substances with larger particles remain mixed evenly together. Like a suspension, this can be difficult to model using 3D model atoms. Colloids can also be represented using percentages.

solution
a mixture of a solute dissolved in a solvent

suspension
a cloudy liquid containing insoluble particles

colloid
a type of mixture that always looks cloudy because clumps of insoluble particles remain suspended throughout it rather than settling as sediment

5.4 Check your learning

Retrieve

1 **Identify** the symbol and colour used to represent each of the following atoms.
  - a hydrogen
  - b carbon
  - c oxygen
  - d nitrogen

2 **Identify** the chemical formula for each of the following molecules.
  - a water
  - b carbon dioxide
  - c methane
  - d oxygen

3 **Define** the term 'solution'.

Comprehend

4 **Describe** how sea water can be modelled.

5 **Describe** how water vapour can be modelled.

6 **Explain** why a mixture cannot be represented by a formula.

Analyse

7 **Contrast** (the differences between) a suspension and a colloid.

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

5.5 Physical change is a change in shape or appearance

Learning intentions

By the end of this topic, you will be able to:

- define vaporise, vapour, fumes, volatile, boiling, condense, melt and sublimation
- describe the processes involved in each change of state.

Key ideas

- 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)

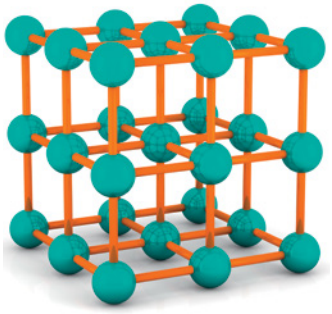


Figure 2 Particles in a solid may be arranged in a lattice.

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** (Figure 2). 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

5.5A: Melting chocolate
Go to page **202**.

CHALLENGE

5.5B: Exploring physical changes
Go to page **203**.

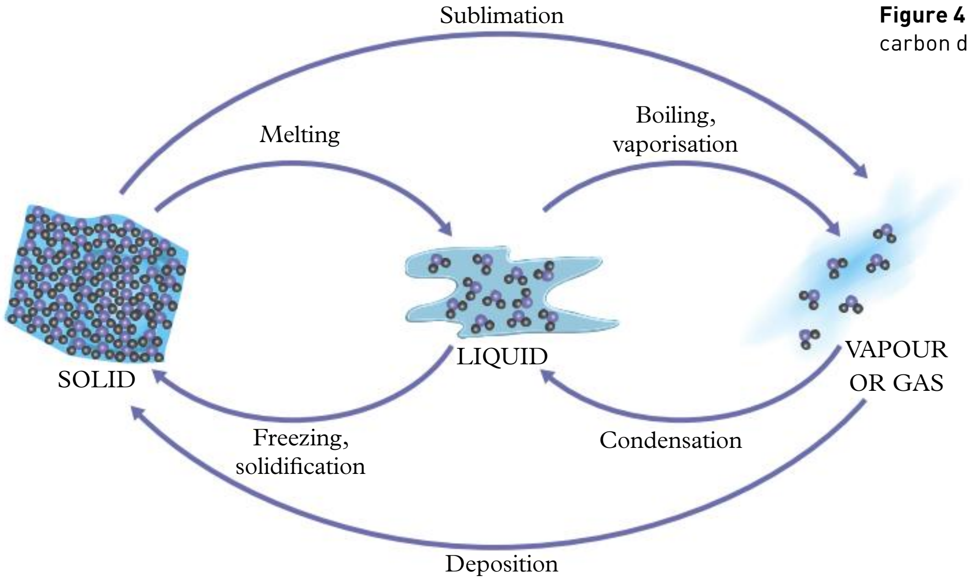


Figure 3 Changing states of water molecules. A solid contains lattice water molecules, a liquid contains a loose arrangement of water molecules and vapour or gas contains separated water molecules.

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).

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
melt	change state from solid to liquid
sublimation	a change of state from a solid directly to a gas

5.5 Check your learning

Retrieve

1 **Define** the following terms.
  a lattice
  b sublimation
  c condense
  d volatile

Comprehend

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.

5 **Illustrate** the three major states of water. **Identify** the physical changes the water goes through to form ice and water vapour.

Apply

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).

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

5.6 Chemical change produces new substances

Learning intentions

By the end of this topic, you will be able to:

- explain the difference between chemical and physical changes and provide examples of each
- identify the features of a chemical change.

Interactive 5.6
Physical and chemical changes

Key ideas

- 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.

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. This is an example of chemical change. It cannot be reversed.

First Nations Australians use 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 things shown in Figures 2 to 5 occurs.

Figure 2 A gas is produced, which we either see as bubbles or fizz.

CHALLENGE

5.6A: Making caramel
Go to page **204**.

EXPERIMENT

5.6B: Observing chemical reactions
Go to page **205**.

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. When the atoms in sodium metal and water rearrange themselves, the extra energy is released as light and heat.

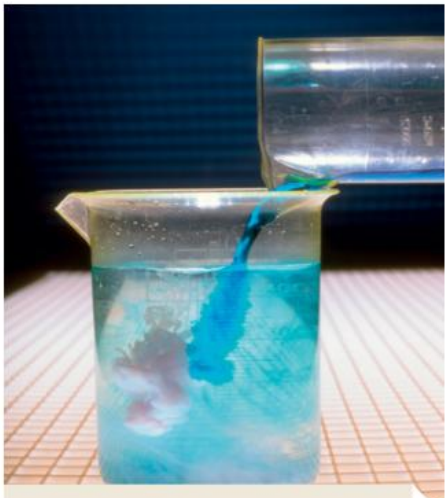


Figure 5 A precipitate forms. A precipitate is the name given when new solid particles form during a chemical change.

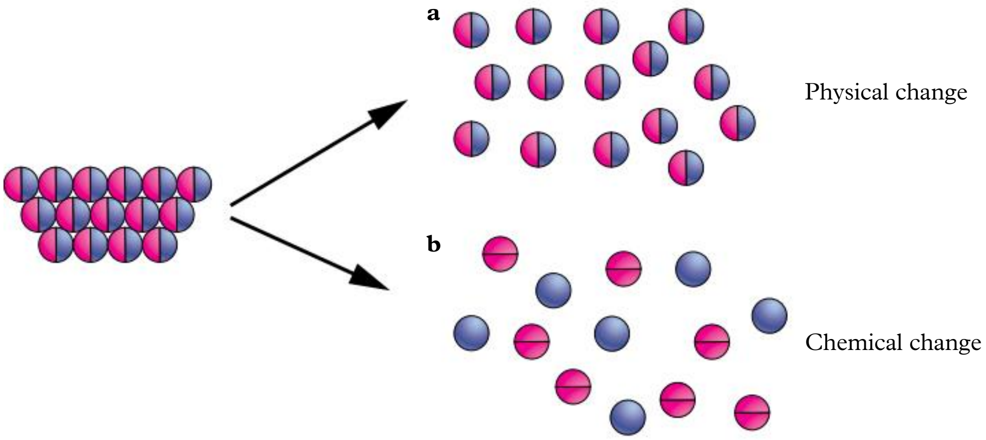


Figure 6 In **a** a physical change, only the appearance of the substance changes because the particles have been rearranged. In **b** a chemical change, atoms are rearranged and new chemicals are made.

5.6 Check your learning

Comprehend

1 **Describe** the observations that would tell you that a chemical change had occurred.

2 Sugar turns brown when heated in a process called caramelisation. **Explain** why caramelisation is considered a chemical reaction.

3 **Describe** the evidence that baking a cake from egg, flour and butter is a chemical reaction.

Analyse

4 **Contrast** (the differences between) chemical and physical change.

5 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.

6 **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

7 **Identify** the key evidence that suggests that producing the reddish-brown pigment from yellow ochre is a chemical change.

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

5.7

Chemical reactions can break bonds and re-form new bonds

Learning intentions

By the end of this topic, you will be able to:

- identify the reactants and products in a chemical reaction
- describe the purpose of chemical equations.

Key ideas

- 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 (Figure 1).

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.

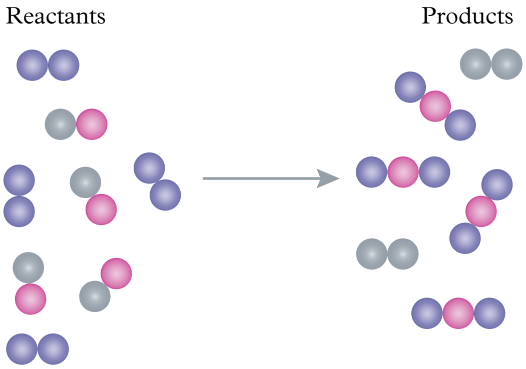


Figure 1 Reactants in a chemical reaction become products.

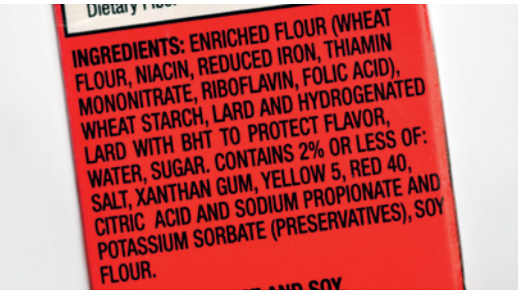
Reactions in cooking

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 2).



INGREDIENTS: ENRICHED FLOUR (WHEAT FLOUR, NIACIN, REDUCED IRON, THIAMIN MONONITRATE, RIBOFLAVIN, FOLIC ACID), WHEAT STARCH, LARD AND HYDROGENATED LARD WITH BHT TO PROTECT FLAVOR. CONTAINS 2% OR LESS OF: WATER, SUGAR, SALT, XANTHAN GUM, YELLOW 5, RED 40, CITRIC ACID AND SODIUM PROPIONATE AND POTASSIUM SORBATE (PRESERVATIVES), SOY FLOUR.

Figure 2 Some processed foods have artificial chemicals added to them.

EXPERIMENT
5.7: Comparing reactants and products
Go to page **206**.

Combustion

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.

First Nations peoples carefully control the burning of plants and wood so that there are only small amounts of oxygen as a reactant. This means that good-quality charcoal is produced (the product) that can then be used for black pigment (Figure 3) 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).

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)
$2\ \mathrm{Mg} + \mathrm{O}_2 \rightarrow \mathrm{MgO}$

combustion
a reaction that involves oxygen and releases light and heat energy

Figure 4 Nylon thread is made by mixing two solutions.

5.7 Check your learning

Retrieve

1 Define the following terms.
   - **a** reactant
   - **b** product

Comprehend

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.

Analyse

4 **Contrast** (the differences between) 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.

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

5.8 Chemical reactions can be sped up and slowed down

Learning intentions

By the end of this topic, you will be able to:

- define collision theory, concentration, catalyst and enzyme
- explain factors that increase the rate of a reaction.

Key ideas

- 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.

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.

collision theory
a theory stating that the particles involved in a chemical reaction must collide in order to react

One way to increase the number of collisions between particles is to increase the temperature (Figure 1). 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 (Figure 2).

concentration
the number of active molecules in a set volume of solution

Figure 1 An increase in temperature causes reactant particles to move faster.

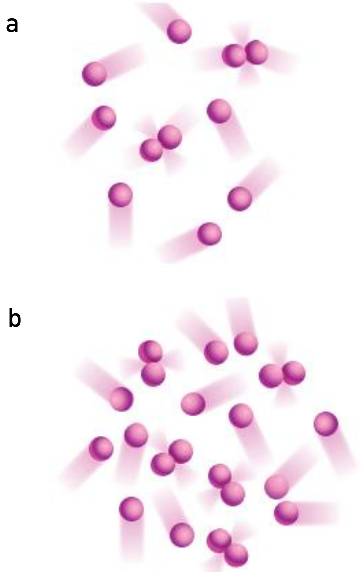


Figure 2 a At low concentrations there are few collisions between particles. **b** At high concentrations, the number of collisions between particles is increased.

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 3).

EXPERIMENT

5.8A: Effect of particle size on reaction rates
Go to page **207**.

EXPERIMENT

5.8B: Speeding up reactions with enzymes
Go to page **208**.

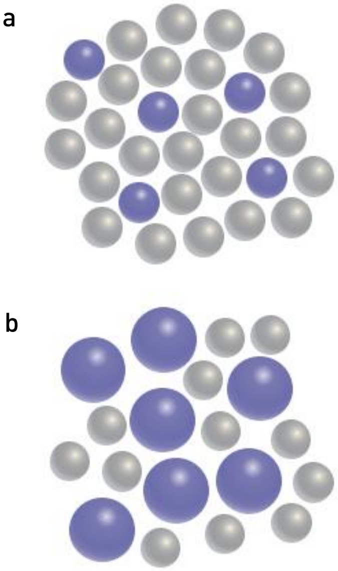


Figure 3 a More reactants can interact or touch each other when the reactant pieces are small. **b** Large reactant pieces have less total surface area to make contact with other reactants.

The effect of catalysts

Adding another substance or material may also affect the rate of a 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 (Figure 4).

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

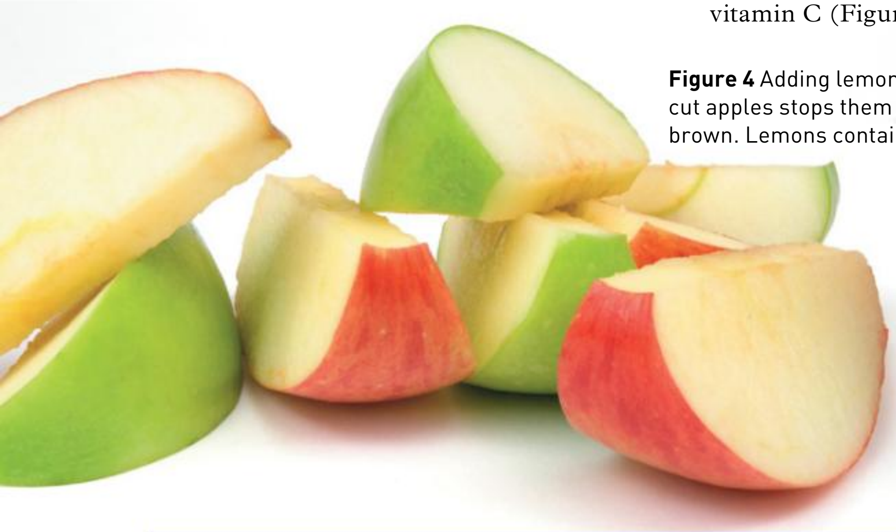


Figure 4 Adding lemon juice to cut apples stops them going brown. Lemons contain vitamin C.

Figure 5 Why does roasting a marshmallow make it go brown?

5.8 Check your learning

Comprehend

1 **Explain** the collision theory in your own words.

2 **Describe** how the surface area of a solid reactant affects the rate of a chemical reaction.

3 **Describe** the effect enzymes have on the rate of a reaction.

4 **Describe** what happens to the number of particles when you increase the concentration of a substance.

5 **Explain** how increasing the concentration of reactants increases the rate of a reaction.

6 **Explain** why increasing the rate of a reaction does not change the total amount of product produced.

Analyse

7 **Consider** how the particle model of matter helps to explain the rate of reactions.

Quiz me
Complete the Quiz me to check how well you’ve mastered the learning intentions and to be assigned a worksheet at your level.

//SCIENCE AS
A HUMAN ENDEAVOUR//

5.9

Many substances exist because of the work of scientists

Learning intentions

By the end of this topic, you will be able to:

- describe how chemical reactions are used in everyday life
- provide examples of everyday experiments.

It is easy to forget just how much we rely on manufactured products in our lives. Increasingly, many substances and materials are processed (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, 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 many more products.

EXPERIMENT

5.9: Making casein glue
Go to page **209**.

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 the shells of murex whelk sea snails. It took 12 000 snails to make just 1.4 g of purple 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.

5.9 Test your skills and capabilities

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 Post-it notes.

//SCIENCE AS A HUMAN ENDEAVOUR//

5.10 Physical and chemical changes are used to recycle household waste

Learning intentions

By the end of this topic, you will be able to:

- classify the processes involved in recycling plastic as physical or chemical changes
- explain the benefits of recycling.

Understanding the difference between physical and chemical change can help us to understand which objects can be recycled. Objects that can undergo physical change can be easily recycled because the changes are reversible and new shapes can be formed. Chemical change can be used to create new materials that can be used again. These two processes can be used to reduce the amount of rubbish that goes into landfill areas.

Types of plastic

As you discovered in Topic 5.9, 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 plastics belong in one of seven groups (Figures 2 to 8). Many plastics are not **biodegradable**; this means that when they end up in landfill or are disposed of it takes a long time (up to thousands of years) before they begin to break down. Some plastics have such strong bonding that they do not ever naturally break down. To protect our environment, it is crucial that we switch to biodegradable plastics and recycle the plastics we use.

biodegradable capable of being decomposed by bacteria or other living organisms and reabsorbed into the natural environment

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 them into small pellets so that the plastic 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

Figure 1 Water bottles use plastic.

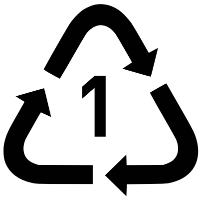


Figure 2 Polyethylene terephthalate (PET or PETE) is the plastic used to make soft drink bottles and oven-ready meal trays.

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.

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.

Recycling of metals

Metals such as iron can be easily recycled using physical change. 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.

$$\text{iron} + \text{oxygen} \rightarrow \text{iron oxide}$$

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.

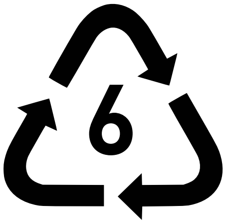


Figure 7 Polystyrene (PS) is used to make foam meat or fish trays, coffee cups, plastic cutlery and sandwich boxes.

Figure 8 Group 7 contains all other plastics, including nylon and fibreglass, that cannot be recycled.

5.10 Test your skills and capabilities

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 different 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 money it 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** (the similarities and differences between) your chosen recycling method and 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.

CHAPTER 5 REVIEW

PHYSICAL AND CHEMICAL CHANGE

Retrieve

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 **Identify** the new substance produced in a chemical reaction.

- **A** the chemical
- **B** the result
- **C** the product
- **D** the reactant

3 **Identify** 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.

4 **Identify** which of the following can be represented by a formula.

- **A** colloid
- **B** suspension
- **C** compound
- **D** solute

5 **Recall** which of the following scientists generated the modern version of the periodic table.

- **A** Democritus
- **B** Dalton
- **C** Mendeleev
- **D** Lavoisier

Comprehend

6 **Define** the term 'reactant' (in a chemical reaction).

7 Use the particle model to **explain**:

- **a** melting
- **b** freezing
- **c** sublimation
- **d** condensation.

8 **Describe** the changes that might be observed during a chemical change.

9 Using your knowledge of particles, **explain** why most physical changes can be reversed.

10 **Describe** four ways to speed up a chemical reaction. Use the particle model to explain why each method works.

11 **Explain** why nylon is described as a synthetic material.

12 **Explain** why chemists would never write a chemical equation for the melting of chocolate.

Figure 1 Chocolate can be easily burnt.

13 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.

14 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.

Analyse

15 **Identify** the number of hydrogen atoms in HCl.

- **A** one
- **B** two
- **C** three
- **D** none

16 **Identify** an object in your home or classroom that is made from PVC.

17 **Contrast** a physical change and a chemical change.

18 **Contrast** a group and a period in the periodic table.

Apply

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 **evaluate** whether the changes described are useful or harmful.

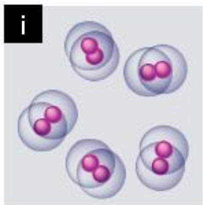
- **a** A bike is left out in the rain so that parts of the bike that are made of steel are in contact with water for a few hours.
- **b** A barbecue fuelled by propane gas is turned on.
- **c** A hairdresser applies bleach to someone's hair.

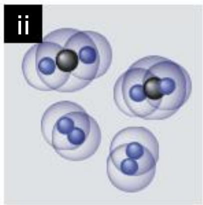
20 **Create** a drawing of a reactant and a product that represents a chemical change.

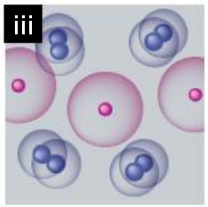
21 **Identify** which of these diagrams show:

- **a** a mixture of an element and a compound
- **b** a mixture of two elements
- **c** a pure element.

Justify your decisions (by defining each term and describing how this matches the diagram).







22 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.

23 Think about your morning routine from when you wake up to when you arrive at school. **Discuss** 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?

24 Substances can change when they interact with each other. In each of the following situations, a change is described. For each change, **determine** 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

25 An environmental action group wants to ban the use of chemicals in your school.

Either:

- **a** Write a letter to your school principal **proposing** why you think this would be a good idea.

Or:

- **b** Write a letter to the leader of the environmental group **proposing** why you think this is a bad idea.

Critical and creative thinking

26 The use of chemistry to produce new materials has affected people's lives in a range of ways.

- **a** **Discuss** how new materials have changed the type of clothes that people wear.
- **b** **Discuss** how new materials have changed the type of food that people eat.

27 **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 describes the danger and offers a solution.

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.

» 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.

- Describe the chemical reactions that could be used by magicians.
- Describe the physical changes that could be used in tricks performed by magicians.
- Explain how the ‘magic’ happens.

» Explosives

Explosions are chemical reactions that release enormous amounts of light, heat and sound very quickly. Dynamite is one of the first explosive chemical reactions that was controlled.

- Identify the person who developed dynamite from nitroglycerine.
- Explain why they were trying to control the chemical reaction.
- Describe how dynamite was used in mining.
- Describe how dynamite was used in wars.
- The person who developed dynamite was horrified at how their discovery was used in war. Identify how the money they accumulated was used to ‘benefit humankind’.

Figure 4 Dynamite is an explosive.

» Soil testing

Some plants grow better in soils that contain certain amounts of nutrients. Gardeners who know this can test the soil to determine the amount of nutrients in the soil.

- Investigate a soil test that has a colour change if it is positive.
- Investigate the chemical reaction that causes this colour change.
- Identify the name of the nutrient and its chemical formula.
- Describe what will happen to a plant if this nutrient is not present.
- Describe how this nutrient could be added to the soil if it is needed.

Figure 5 This soil is growing healthy plants.

» 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.

- Identify the chemicals that are present in LPG.
- Compare gas barbecues and solid fuel barbecues.
- Describe the safety precautions that must be followed when storing LPG cylinders.
- Describe what could happen if an LPG cylinder is exposed to high temperatures.

Figure 6 A home barbecue with a gas cylinder

Chapter checklist

Now that you have completed this chapter, reflect on your ability to do the following.

	I can do this.	I cannot do this yet.
• Describe the development of atomic theory over time. • Identify the main scientists who contributed to the development of the periodic table.	☐	☐ Go back to Topic 5.1 'All matter is made up of atoms'. Page 94
• Define and describe the key features of the periodic table including periods, groups, elements, monatomic gases and diatomic gases. • Describe the relationship between an element's atomic number and atomic mass, and its subatomic particles.	☐	☐ Go back to Topic 5.2 'Elements are made up of one type of atom'. Page 96
• 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 5.3 'Atoms bond together to make molecules and compounds'. Page 98
• Describe how elements, compounds, molecules and mixtures can be modelled. • Contrast suspensions and colloids.	☐	☐ Go back to Topic 5.4 'Matter can be modelled'. Page 100
• Define vaporise, vapour, fumes, volatile, boiling, condense, melt and sublimation. • Describe the processes involved in each change of state.	☐	☐ Go back to Topic 5.5 'Physical change is a change in shape or appearance'. Page 102
• Explain the difference between chemical and physical changes and provide examples of each. • Identify the features of a chemical change.	☐	☐ Go back to Topic 5.6 'Chemical change produces new substances'. Page 104
• Identify the reactants and products in a chemical reaction. • Describe the purpose of chemical equations.	☐	☐ Go back to Topic 5.7 'Chemical reactions can break bonds and re-form new bonds'. Page 106
• Define collision theory, concentration, catalyst and enzyme. • Explain factors that increase the rate of a reaction.	☐	☐ Go back to Topic 5.8 'Chemical reactions can be sped up and slowed down'. Page 108
• Describe how chemical reactions are used in everyday life. • Provide examples of everyday experiments.	☐	☐ Go back to Topic 5.9 'Science as a human endeavour: Many substances exist because of the work of scientists'. Page 110
• Classify the processes involved in recycling plastic as physical or chemical changes. • Explain the benefits of recycling.	☐	☐ Go back to Topic 5.10 'Science as a human endeavour: Physical and chemical changes are used to recycle household waste'. Page 112

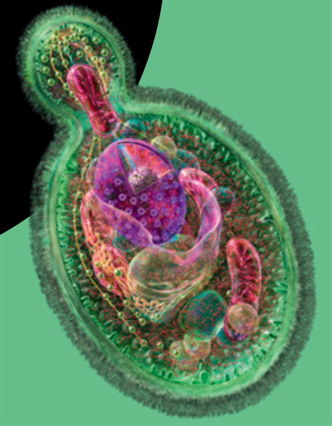
Check your Student obook pro for these digital resources and more:

Quizlet
Play a Quizlet game to test your knowledge.

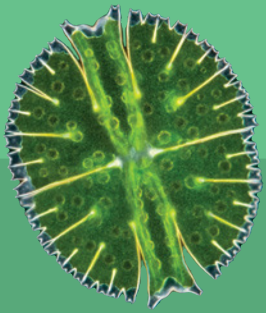
Chapter quiz
Test your understanding of this chapter with the chapter review quiz.

CHAPTER

6



CELLS



6.1

All living things are made up of cells

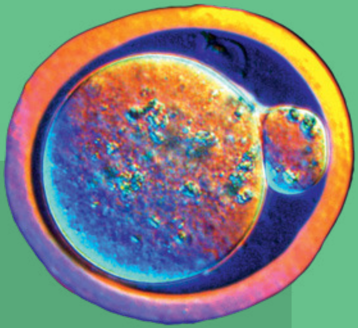
- > Explain the key concepts of cell theory.
- > Describe surface area to volume ratio.

6.2

Microscopes are used to study cells

- > Compare stereomicroscopes and compound light microscopes.
- > Compare electron and light microscopes.
- > Calculate magnification.
- > Focus a compound light microscope.

6.3



Plant and animal cells have organelles

> Describe the functions of the cell membrane, cytoplasm, DNA, mitochondria, cell wall, chloroplasts and vesicles.

> Identify the key differences in the structures of animal and plant cells.

6.4

Cells have different roles

> Describe the key differences between prokaryotic and eukaryotic cells.

> Recall examples of prokaryotic and eukaryotic cells.

6.5

Single-celled and multicelluar organisms can cause disease

> Describe the differences between natural flora and pathogens.

> Identify whether types of pathogens are single-celled or multicellular.

> Describe the process of binary fission.

6.6

Science as a human endeavour: Fungal cells can save lives

> Explain the relationship between bacterial cells and some fungal cells.

> Describe the development of fungal cells as a medical treatment.

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

Learning intentions

By the end of this topic, you will be able to:

- explain the key concepts of cell theory
- describe surface area to volume ratio.

Key ideas

- 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

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**.

cell
(in biology) the building block of living things

microbiology
the science involving the study of microscopic organisms

cell theory
theory describing the properties that all cells have in common

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.

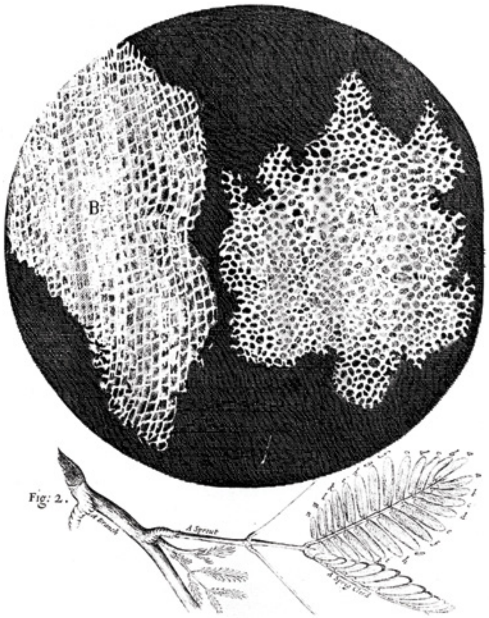


Figure 1 Robert Hooke's drawing of cork

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.

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** (Figure 2a). There are many living things, such as bacteria, that consist of only one cell. These are called **single-celled** or unicellular organisms (Figure 2b). **Microorganisms**, 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.

multicellular
an organism that has two or more cells

single-celled
an organism that consists of one cell

microorganism
a living thing that can only be seen with the use of a microscope

SKILLS LAB

6.1: Drawing cells
Go to page **210**.

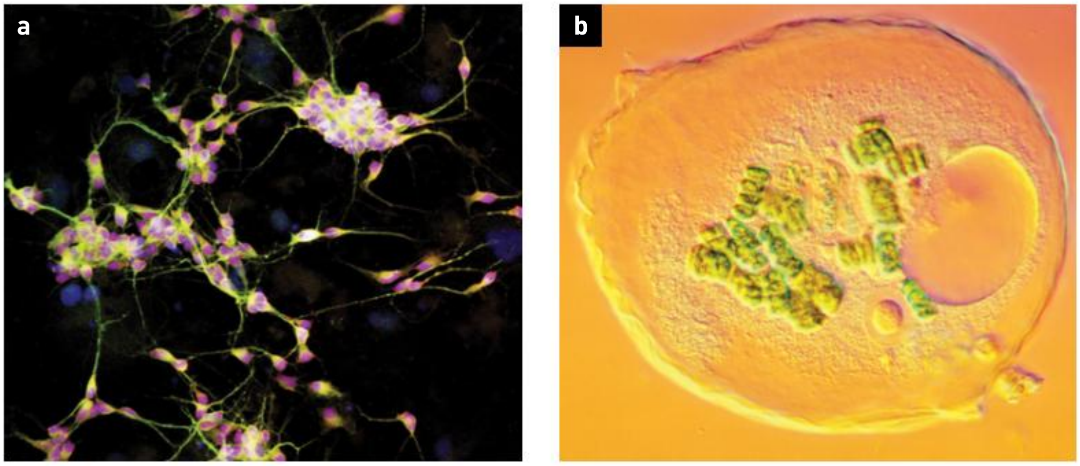


Figure 2 a Human nerve cells are part of multicellular humans, but **b** the amoeba is a single-celled organism.

cell membrane
the barrier around a cell that controls the entry and exit of substances into and out of the cell

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 (Figure 3).

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.

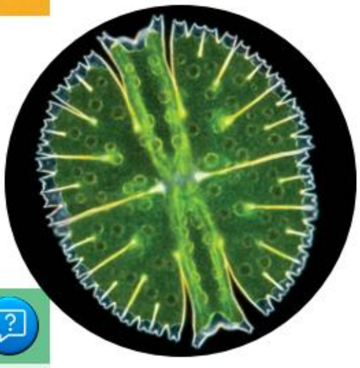


Figure 3 The irregular shape of this single-celled organism (called a desmid) maximises the surface area to volume ratio.

6.1 Check your learning

Retrieve

1 **Name** the person who invented the first microscope.
2 **Recall** why cells are called 'cells'.
3 **Define** the term 'multicellular'.
4 **Name** five multicellular organisms.
5 **Identify** three things that all single-celled organisms have in common.
6 **State** the three principles of cell theory.

Comprehend

7 The common house dust mite is a microorganism. **Recall** whether you would be able to see this animal without a microscope. **Explain** your answer (by defining the term 'microorganism' and linking the definition to the need for a microscope).
8 **Explain** whether a cell with a bigger surface area to volume ratio would be able to meet its requirements for nutrients effectively.
9 **Explain** why single-celled organisms are very small.

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

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

Learning intentions

By the end of this topic, you will be able to:

- compare stereomicroscopes and compound light microscopes
- compare electron and light microscopes
- calculate magnification
- focus a compound light microscope.

Video 6.2
Microscopes are used to study cells

Key ideas

- 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.

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**.

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 (Figure 1a). 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 (Figure 1b). 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.

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 create the image, showing details of the specimen's surface (Figure 2).

Electron microscopes can magnify up to a million times. Using this technology, many more details of the cell can be seen and understood.

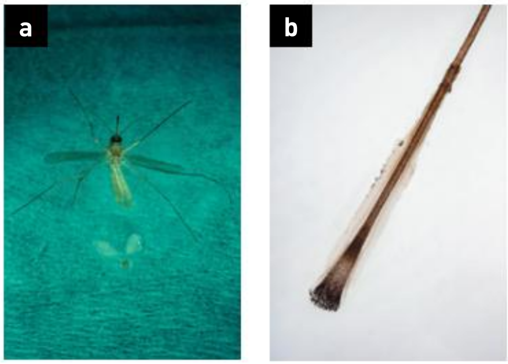


Figure 1 a An insect, as seen under a stereomicroscope **b** Human hair root as seen under a compound light microscope

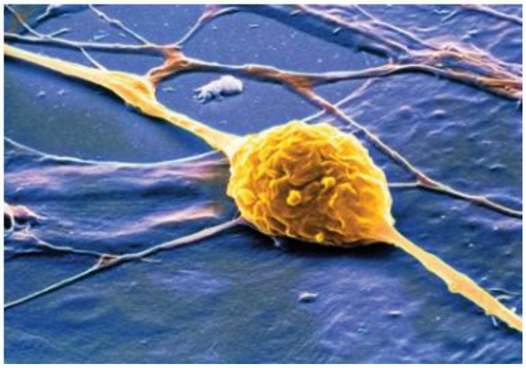


Figure 2 Image of a nerve cell under a scanning electron microscope (SEM)

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
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

SKILLS LAB
6.2: Getting to know your microscope
Go to page **211**.

Using a compound light microscope

Figure 3 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.

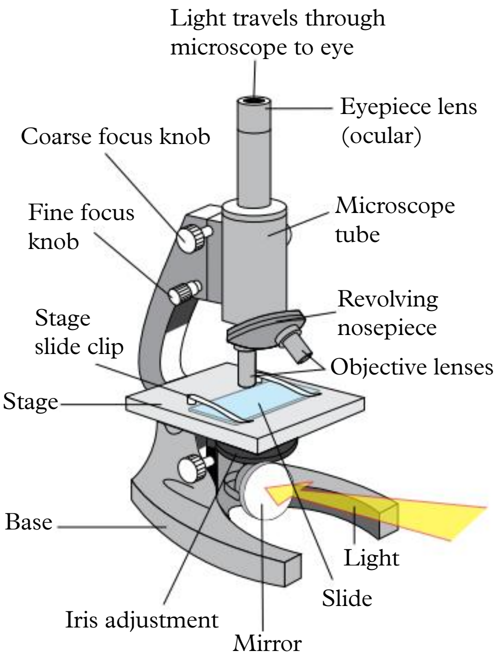


Figure 3 Parts of a compound light microscope

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.

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

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

Retrieve

1 **Define** the term ‘microscopy’.
2 **Recall** why very thin samples should be used under a light microscope.

Analyse

3 **Identify** the type (or types) of microscopes in your science laboratory.
4 **Infer** why you should look from the side when first adjusting the coarse focus knob.
5 **Compare** (the similarities and differences between) stereomicroscopes and compound light microscopes.
6 **Contrast** (the differences between) TEM and SEM.
7 **Calculate** the missing values in the following magnification table.

Eyepiece magnification	Objective lens magnification	Total magnification
× 5		× 100
	× 20	× 300
× 10	× 50	

Quiz me
Complete the Quiz me to check how well you’ve mastered the learning intentions and to be assigned a worksheet at your level.

6.3

Plant and animal cells have organelles

Learning intentions

By the end of this topic, you will be able to:

- describe the functions of the cell membrane, cytoplasm, DNA, mitochondria, cell wall, chloroplasts and vesicles
- identify the key differences in the structures of animal and plant cells.

Key ideas

- 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.

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).

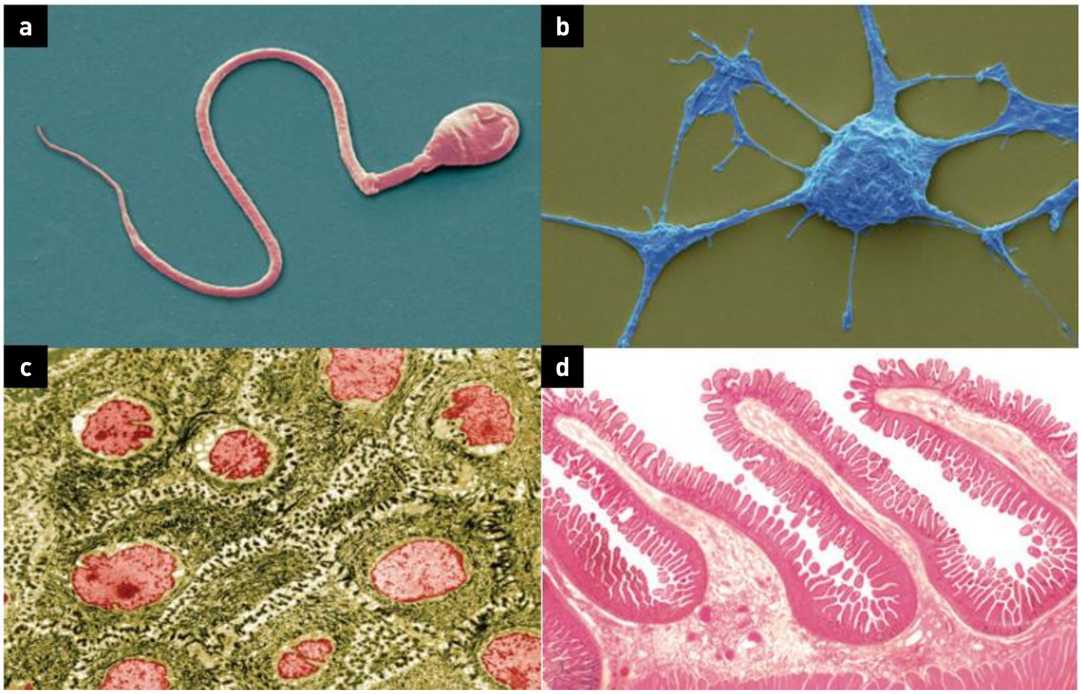


Figure 1 Cells can be different shapes and sizes: **a** sperm cell, **b** nerve cell, **c** skin cell and **d** intestinal cell.

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

CHALLENGE

6.3A: Comparing the size of cells and their parts
Go to page **212**.

AN ANIMAL CELL

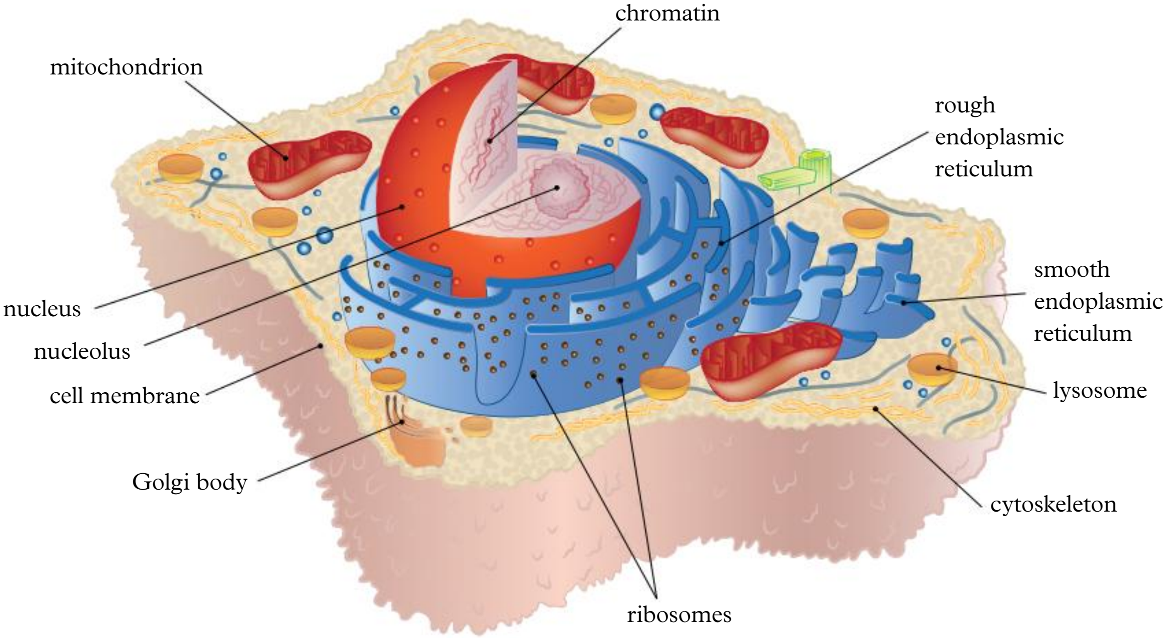


Figure 2 Some key parts (organelles) of an animal cell

A PLANT CELL

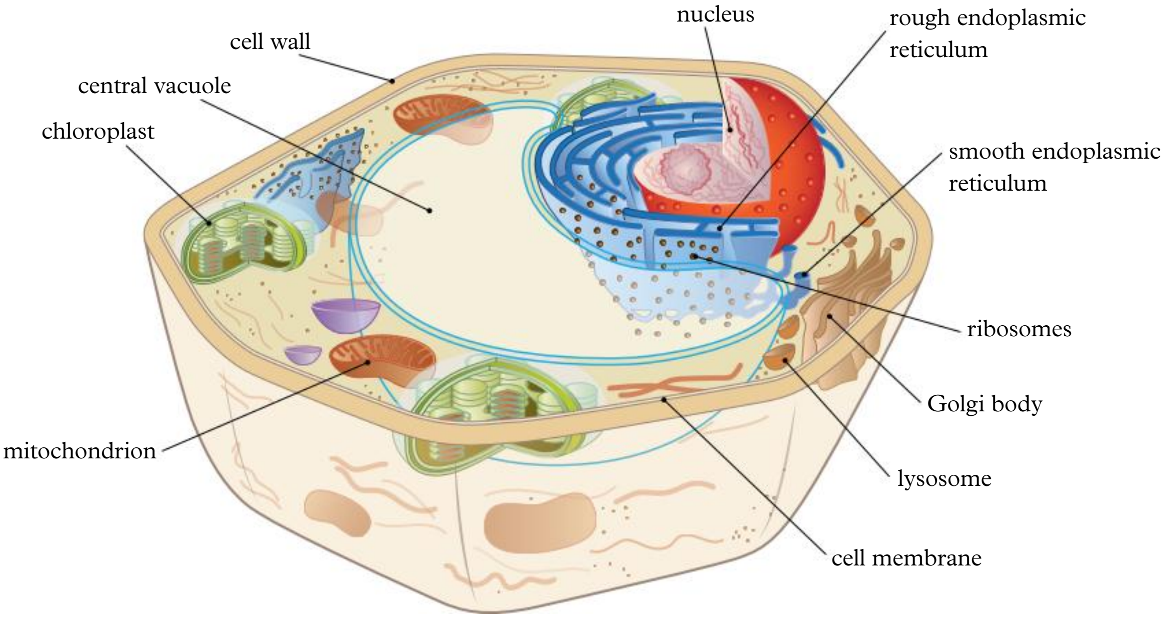


Figure 3 Some key parts (organelles) of a plant cell

A closer look at organelles

Some cells need special areas or **organelles** (mini-organs) to help them do special things (perform functions) (Figures 2 and 3). 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, cell wall, 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)

cell wall
the outer protective and support structure of a plant cell

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

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 (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.

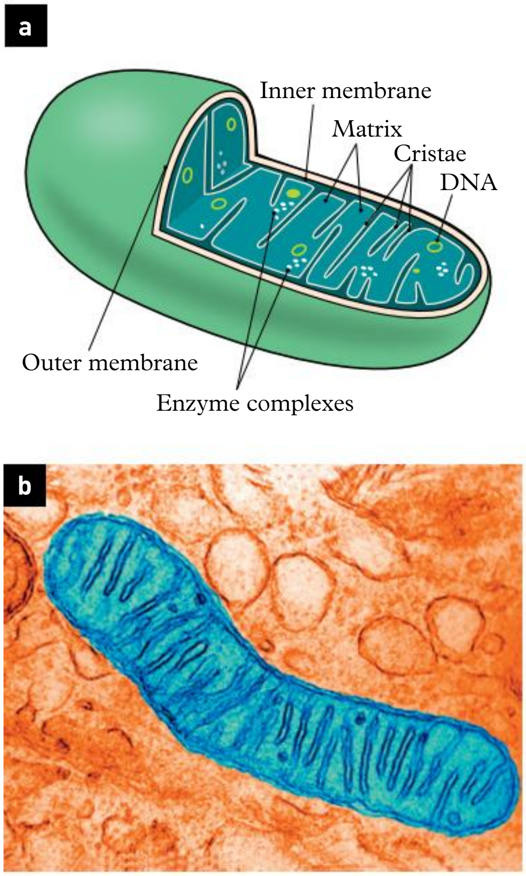


Figure 4 a Schematic diagram showing the structure of a mitochondrion **b** Electron micrograph of a mitochondrion

Cell wall

Cell walls are not found in animal cells. They are found around the outside of plant cells, fungal cells and bacterial cells (Figure 5). The cell wall is important for helping the cell keep its shape, especially in fresh water. Fresh water can easily enter a cell, making the outside membrane swell and possibly burst. If the cell is surrounded by a cell wall, the membrane cannot burst.

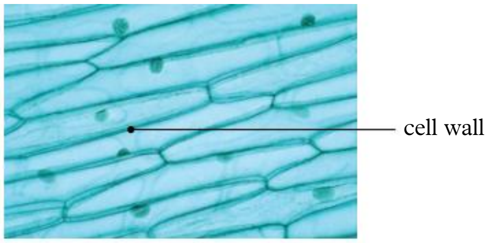


Figure 5 Light micrograph of plant cells showing the cell walls

Chloroplasts

Chloroplasts are only found in plant cells and some unicellular organisms (Figure 7). 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**.

Figure 6 The chlorophyll in plants uses the Sun's light energy to create glucose and oxygen.

EXPERIMENT

6.3B: Looking at organelles
Go to page **213**.

EXPERIMENT

6.3C: Measuring cells
Go to page **214**.

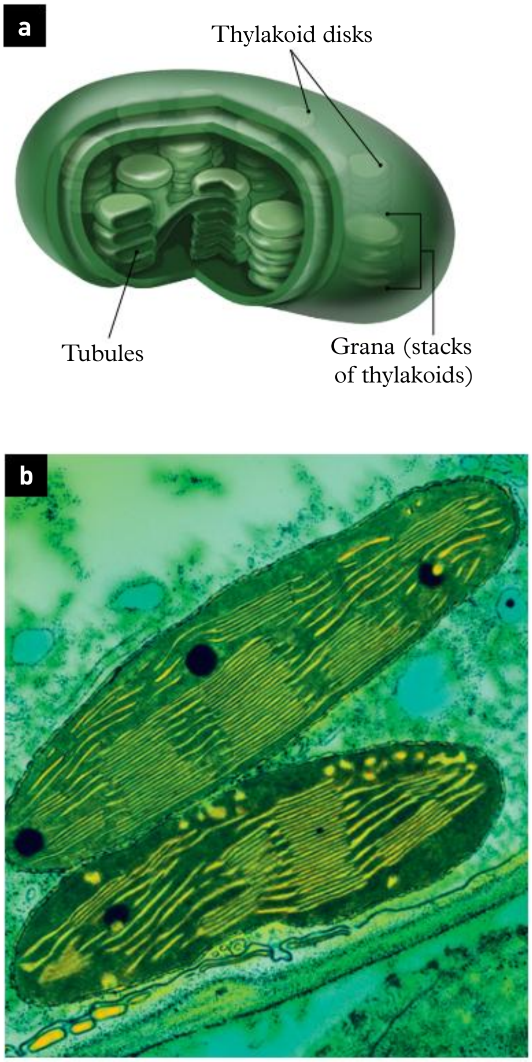


Figure 7 **a** Schematic diagram showing the structure of a chloroplast **b** Electron micrograph of chloroplasts

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. Animal cells may have many small vesicles.

vesicle
an organelle surrounded by a membrane and used by cells to store materials; a vacuole is a type of vesicle found in plant cells

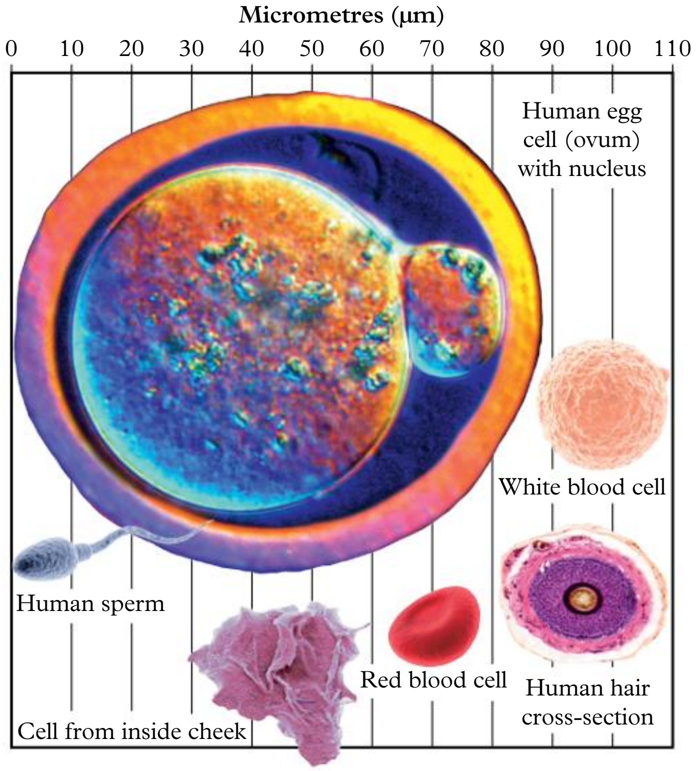


Figure 8 Different types of cells are different sizes and are measured in micrometres (µm). One micrometre is equivalent to one-thousandth of 1 mm.

6.3 Check your learning

Retrieve

1 **Recall** the function of the cell membrane.

2 **Name** the organelle where cellular respiration occurs.

3 **State** three things that are stored in a vacuole.

4 **Identify** three organelles that are surrounded by a membrane.

Comprehend

5 **Describe** the features of all living cells. (HINT: Remember MRNGREWW from Year 7.)

6 **Describe** the role of the cell wall in plants.

7 **Explain** the function of chlorophyll.

Analyse

8 **Identify** the reactants (present at the start) and products (present at the end) for the chemical reaction called photosynthesis.

9 **Contrast** (the differences between) the structure of animal and plant cells.

Apply

10 **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).

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

6.4

Cells have different roles

Learning intentions

By the end of this topic, you will be able to:

- describe the key differences between prokaryotic and eukaryotic cells
- recall examples of prokaryotic and eukaryotic cells.

Key ideas

- All cells can be broken into two groups, prokaryotes and eukaryotes.
- Prokaryotes (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

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. Table 1 lists some of the characteristics of prokaryotic and eukaryotic cells.

prokaryotic cell
primitive single-celled organism that has no nucleus

eukaryotic cell
complex cell that contains a nucleus and membrane-bound organelles

Plant cells

When we look at whole organism plants and animals, it's fairly easy to see that they are different. Once microscopes started to become more powerful, scientists could see differences between plant and animal cells (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 (Figure 2). 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

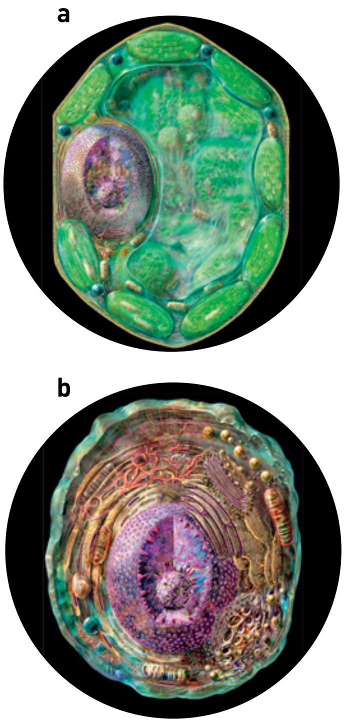


Figure 1 Typical **a** plant and **b** animal cells

CHALLENGE
6.4A: Classifying using cells
Go to page **215**.

EXPERIMENT
6.4B: Plant and animal cells
Go to page **216**.

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 3 to 6 have structures particular to their lifestyles.

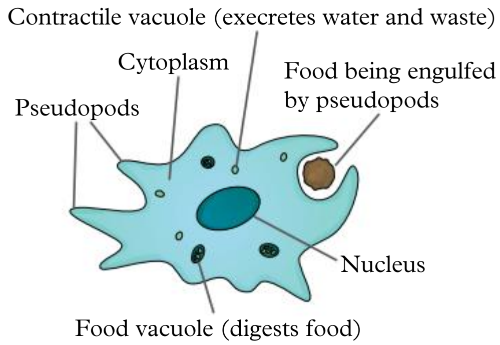


Figure 3 An amoeba can change the shape of its blobby body, creating foot shapes for movement and mouth shapes for swallowing food.

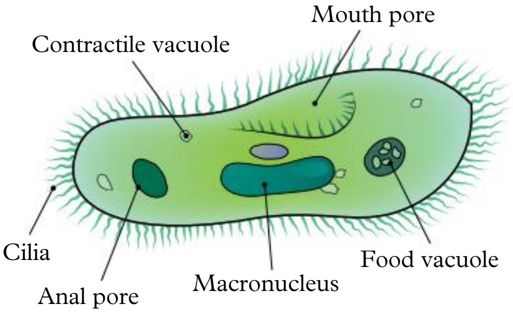


Figure 4 The paramecium moves slowly with lots of tiny hairs called cilia that act like miniature oars.

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 2 Cells in kingdom Fungi have cell walls and nuclei, but no chloroplasts.

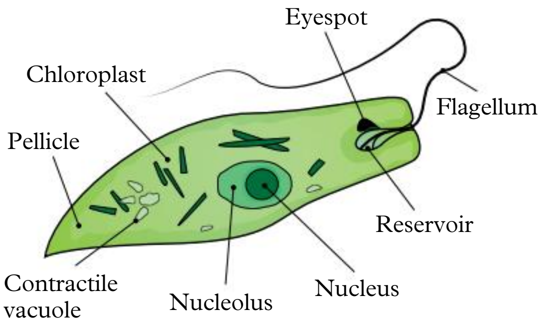


Figure 5 Euglena moves quickly when it needs to, with a bullet-shaped body and a long tail called a flagellum to whip it into action.

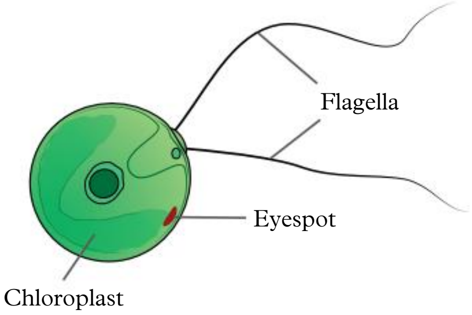


Figure 6 Chlamydomonas has an eyespot to detect light and two flagella to swim.

6.4 Check your learning

Retrieve

1 **State** where the genetic material is found in a prokaryotic cell.

2 **Recall** an example of a unicellular organism and a multicellular organism.

Comprehend

3 **Describe** the two main differences between eukaryotic and prokaryotic organisms.

4 **Illustrate** a cell that would be found in a mushroom (eukaryotic fungal cell). Label all of the organelles.

Analyse

5 Use Table 1 to **identify** the kingdom that is often referred to as 'the rest' of the cells.

6 Table 1 shows that plant cells contain chloroplasts. Although a typical plant cell contains chloroplasts, they are not found in all plant cells.

  a **Infer** 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.

Quiz me

Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

6.5

Single-celled and multicellular organisms can cause disease

Learning intentions

By the end of this topic, you will be able to:

- describe the differences between natural flora and pathogens
- identify whether types of pathogens are single-celled or multicellular
- describe the process of binary fission.

Key ideas

- Non-dangerous bacteria that live on or in 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.

Unicellular organisms, such as bacteria, are living in and around us all the time. The average adult human has 1 kilogram of non-human life inside their large intestine alone. Some bacteria and microbes are essential for keeping our body healthy and working correctly. Others can be deadly. Figure 1 shows different bacteria found in the human body.

Microbes essential for health

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 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 before. Some forms of sickness are caused by pathogens. A **pathogen** is a microorganism that can potentially cause a disease. An **infectious disease** is one where the pathogen is passed from one organism to another. Infectious diseases are described as being contagious. Pathogens always live on a host organism, such as a human, other animal or plant.

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 a contagious disease

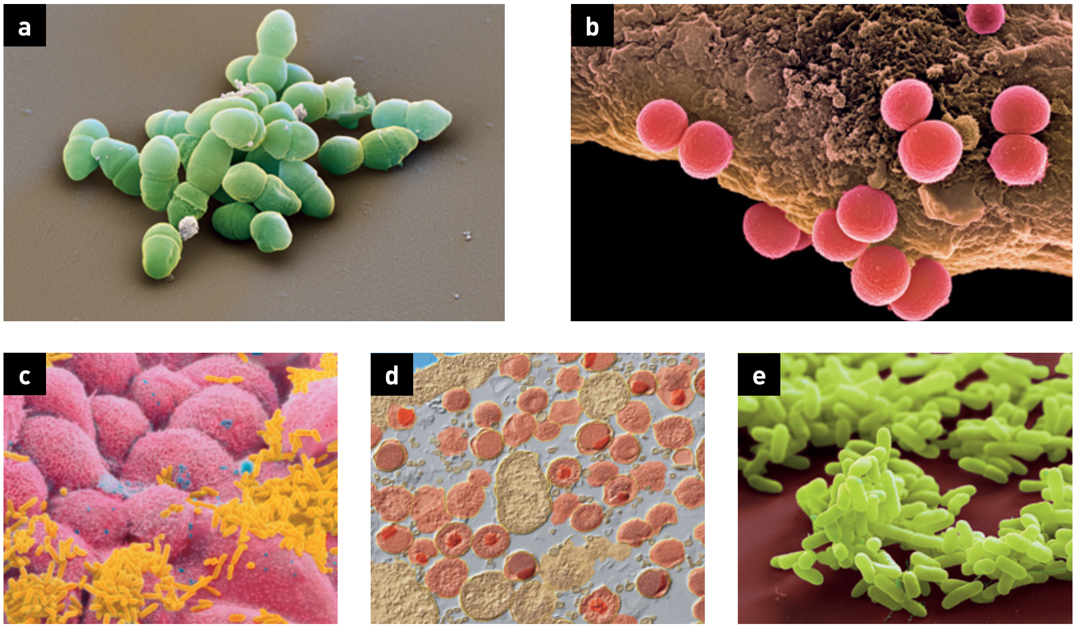


Figure 1 **a** *Staphylococcus epidermis* **b** *Staphylococcus aureus* in the hair **c** *Haemophilus influenza* in the nose **d** *Chlamydia trachamates* in the eye **e** *Esherichia coli* in the intestines

EXPERIMENT
6.5: Microbes all around
Go to page **217**.

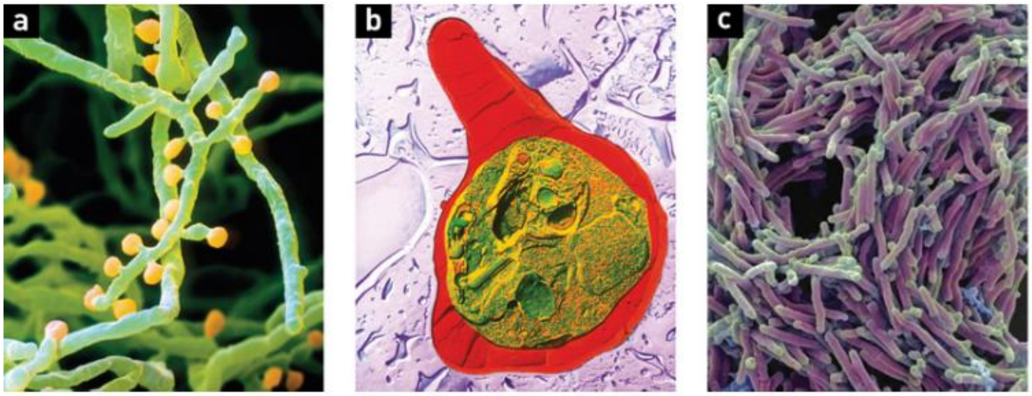


Figure 2 **a** *Trichophyton mentagrophtes* – cause of ringworm and tinea **b** A red blood cell infected with malarial parasites **c** Tuberculosis bacteria

symptoms
the physical or mental signs of a disease

binary fission
a form of asexual reproduction used by bacteria; the splitting of a parent cell into two equal daughter cells

You will investigate pathogens in more detail in Year 9. The **symptoms** of a disease are the changes that occur to a host due to the disease.

Harmful microbes can be viruses, fungi, protists or bacteria. Viruses are considered by most scientists to be non-living pathogens because they cannot survive and reproduce outside a host cell. Instead, they need to invade a cell and use the cell's organelles to reproduce. They are not cells and are much smaller than cells. Viruses are hard to treat with medications because they hide inside our cells. They cannot be treated with antibiotics.

Fungi, protists and bacteria are living organisms made up of cells. Fungi can be single-celled or multicellular. Most protists are single-celled. Bacteria are single-celled. All these microbes can invade the body and cause disease. You are probably 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. Diseases caused by bacteria can be treated with antibiotics, which kill the bacterial cells or stop them reproducing. Microbes causing some of these diseases are shown in Figure 2.

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.

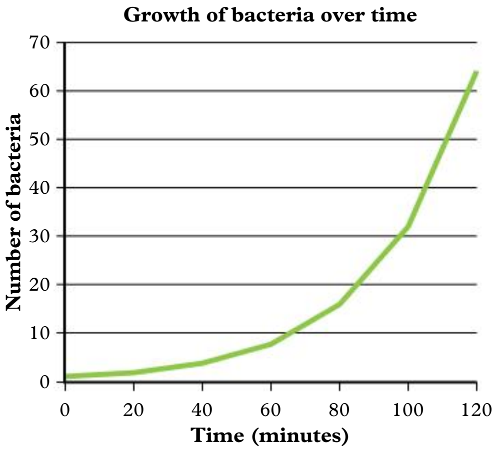


Figure 3 The number of bacteria cells can double every 20 minutes.

6.5 Check your learning

Retrieve

1 **Identify** the type of microorganism that your digestive system relies on.

2 a **Define** the term 'pathogen'.
  b **Identify** the four main types of pathogens.
  c **Recall** whether each of the types of pathogen is single-celled, multicellular or not a cell.

Comprehend

3 **Describe** the process of binary fission.

Analyse

4 **Contrast** (the differences between) natural flora and pathogens.

5 It is not recommended that food be left out of the fridge for more than 3 hours. Use the definition of binary fission to **infer** why.

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

//SCIENCE AS A HUMAN ENDEAVOUR//

6.6 Fungal cells can save lives

Learning intentions

By the end of this topic, you will be able to:

- explain the relationship between bacterial cells and some fungal cells
- describe the development of fungal cells as a medical treatment.

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.

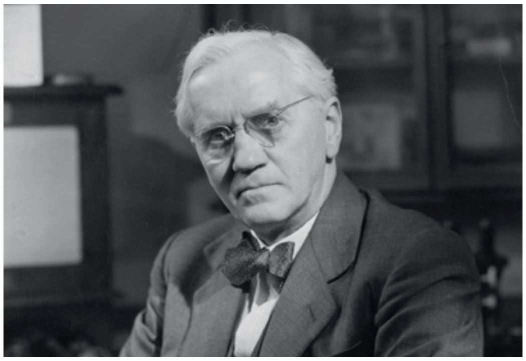


Figure 1 Alexander Fleming

Figure 2 A type of penicillin can grow on orange peels.

The discovery of penicillin

It has been accepted for over 3000 years that some fungal cells can kill bacteria. Alexander Fleming (Figure 1) is credited with discovering in 1928 the specific chemical 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 (Figure 3). The molecule, which was named penicillin, had the ability to stop bacterial growth by preventing the bacteria repairing or making a new cell wall.

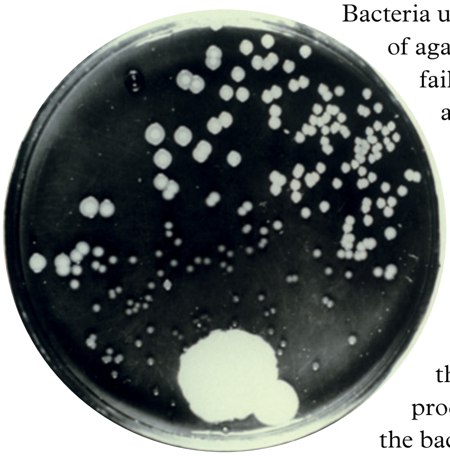


Figure 3 *Penicillium* mould growing on Fleming's agar plate

Producing penicillin

It took ten more years and the work of Howard Florey (an Australian, Figure 4) and Ernst Chain (Figure 5) 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

In May 1940, Fleming's group infected eight mice with streptococcal bacteria. Four of the mice were treated with penicillin. These 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 and the other lanced to drain the pus. Within one day of being given penicillin, Alexander 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 (Figure 6). 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.

The timeline of knowledge development about mould as a treatment for bacterial infection is shown in Figure 7.

Overuse of antibiotics

There are now many 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.

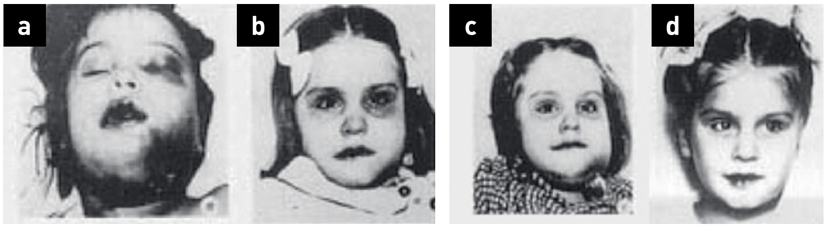


Figure 6 These photos from 1942 show the improvement of a child after penicillin treatment for a bacterial infection.
a Before treatment
b Four days after treatment
c Nine days after treatment
d Fully recovered

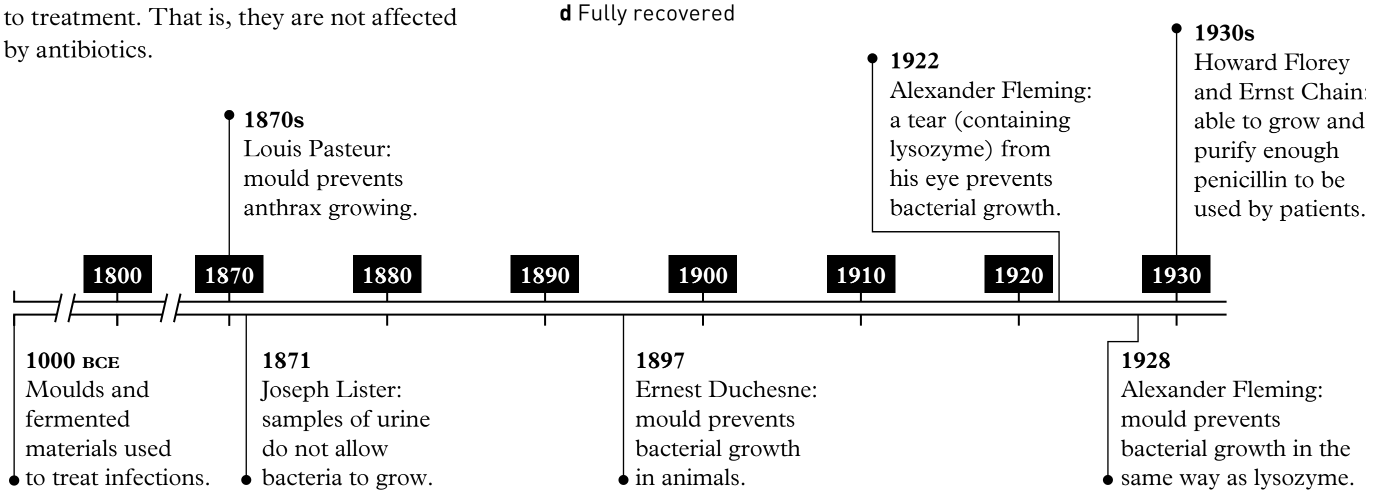


Figure 7 Penicillin timeline

6.6 Test your skills and capabilities

Communicating with your audience

When you are sick, you visit the doctor. Doctors have many years of training to ask questions, observe disease symptoms, diagnose disease and decide if medication is needed. Doctors need to communicate their critical thinking to patients that do not have the same training or understanding. Doctors change the words about concepts so that their audience understands them.

Use your knowledge of viruses like influenza and how antibiotics kill bacteria to **create** a brochure that explains why a patient with influenza cannot be treated with antibiotics. Use the following hints to help you.

Before you begin:

1 **Decide** the age of the person who will read the brochure.

2 **Describe** how much they know about cells and viruses.

In your brochure:

3 **Describe** the symptoms of influenza.

4 **Compare** (the similarities and differences between) bacteria and viruses.

5 **Describe** how antibiotics affect bacteria.

6 **Describe** why antibiotics do not work on viruses.

CHAPTER 6 REVIEW

CELLS

Retrieve

1 **Name** the first person to describe a cell.

2 **Identify** two types of microscopes.

3 **Define** the following terms.
  - a nucleus
  - b mitochondrion
  - c chloroplast
  - d binary fission

4 **Identify** which of the following is not found in an animal cell.
  - A mitochondria
  - B a cell wall
  - C cytosol
  - D a nucleus

5 **Recall** which important process takes place in the mitochondria of a cell.
  - A photosynthesis
  - B excretion
  - C cellular respiration
  - D cell division

6 **Identify** the term that describes an organism that catches a disease.
  - A cell
  - B pathogen
  - C host
  - D organism

Comprehend

7 **Explain** why multicellular organisms are made up of many cells instead of one large cell.

8 **Describe** the benefit of using a stain when viewing some specimens.

9 Cell walls are found in every plant cell on Earth. **Describe** the function of the cell wall.

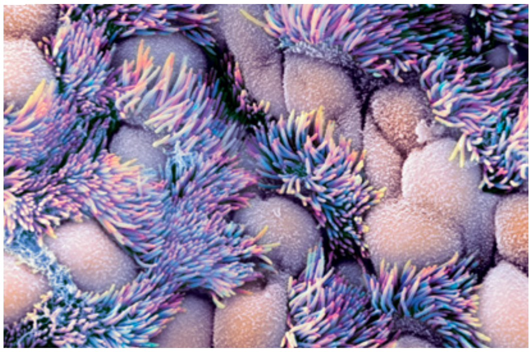
10 **Describe** how our understanding of how living things function changed with the development of the microscope.

Analyse

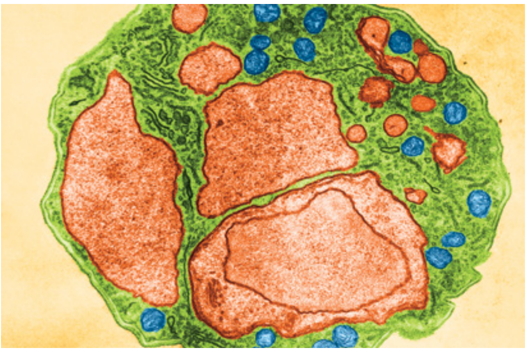
11 **Calculate** the magnification of a cell that is viewed with a '×40' objective lens and a '×10' eye-piece lens.

12 **Identify** the microscope most likely to have created the images below. **Justify** your decision (by describing the features in the picture that are unique and deciding which microscope would allow these features to be seen).

a

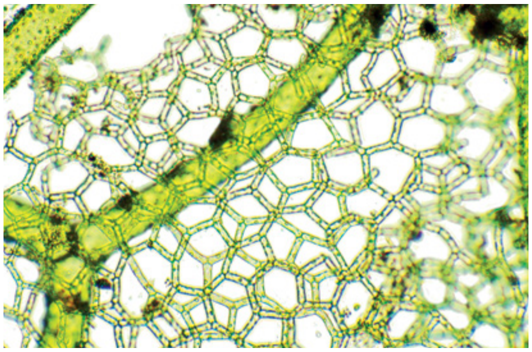


b



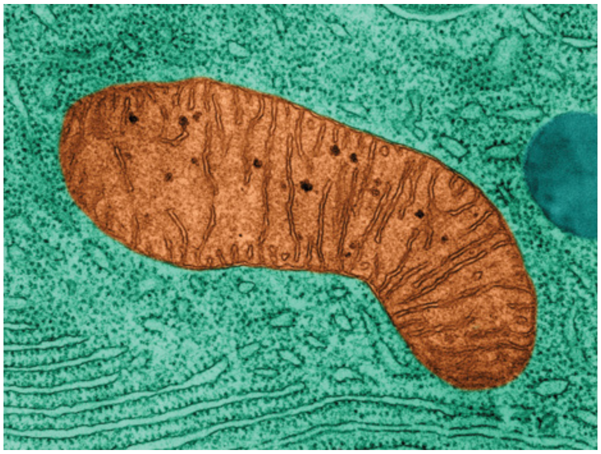
c

d



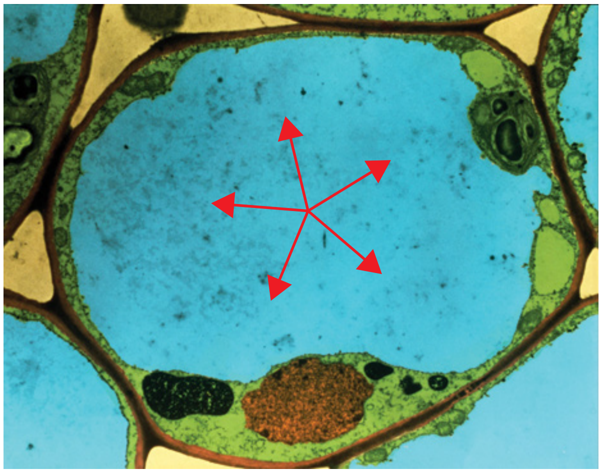
13 **Identify** the following organelles.

a



b

c



14 **Compare** a mitochondrion and a chloroplast.

15 **Contrast** fungal cells and bacterial cells.

16 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.

Apply

17 Two students prepare slides from different sections of a spring onion under a light microscope in their school laboratory. Tran 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 **Propose** why Tran observed 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. **Discuss** whether it is possible for a plant cell not to have 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).

18 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'.

19 Use the lenses from an old pair of reading glasses or a magnifying glass to **create** a model of a microscope. **Discuss** how your model is similar and different to Hooke's microscope and modern compound microscopes.

Critical and creative thinking

20 Similes are often used in creative writing to compare two things using the words 'like' or 'as'. **Discuss** the similarities that allow the following 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.

Social and ethical thinking

21 **Discuss** why a doctor should not prescribe antibiotics for a viral infection by describing:

- a the effectiveness of the antibiotics on making the person healthy
- b the long-term effects of overprescribing antibiotics on bacterial resistance.

Research

22 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

In this chapter, six big concepts about cells were discussed. Consider a creative way to represent these concepts and make links between them, using as many of the key words in the chapter as you can. 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.

Figure 1 Represent the concepts in this chapter creatively.

» 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 again instead of having limbs amputated. Develop and write a newspaper article describing the importance of this major discovery.

Figure 2 The development of penicillin, 1940

» Stem cells

Stem cells are cells in multicellular organisms that haven't become specialised yet – they're like blank canvases. Investigate what scientists have learnt about stem cells, where they find them and what they hope to be able to do with them.

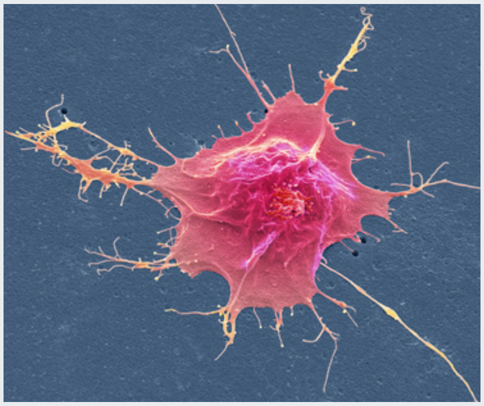


Figure 3 Scanning electron micrograph of a type of pluripotent stem cell

» 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.

- Investigate how stomata open and close in response to changing environmental conditions.
- Describe the conditions that allow the stomata to open.
- Describe the conditions that cause the stomata to close.
- Describe how the shape of the guard cells assists the opening and closing of the stomata.

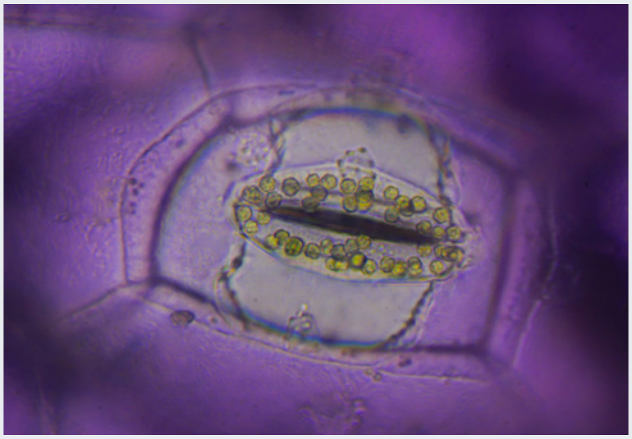


Figure 4 Micrograph of a stomata on a purple and green leaf

Chapter checklist

Now that 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 cell theory. • Describe surface area to volume ratio.	☐	☐ Go back to Topic 6.1 'All living things are made up of cells'. Page 120
• Compare stereomicroscopes and compound light microscopes. • Compare electron and light microscopes. • Calculate magnification. • Focus a compound light microscope.	☐	☐ Go back to topic Topic 6.2 'Microscopes are used to study cells'. Page 122
• Describe the functions of the cell membrane, cytoplasm, DNA, mitochondria, cell wall, chloroplasts and vesicles. • Identify the key differences in the structures of animal and plant cells.	☐	☐ Go back to Topic 6.3 'Plant and animal cells have organelles'. Page 124
• Describe the key differences between prokaryotic and eukaryotic cells. • Recall examples of prokaryotic and eukaryotic cells.	☐	☐ Go back to Topic 6.4 'Cells have different roles'. Page 128
• Describe the differences between natural flora and pathogens. • Identify whether types of pathogens are single-celled or multicellular. • Describe the process of binary fission.	☐	☐ Go back to Topic 6.5 'Single-celled and multicellular organisms can cause disease'. Page 130
• Explain the relationship between bacterial cells and some fungal cells. • Describe the development of fungal cells as a medical treatment.	☐	☐ Go back to Topic 6.6 'Science as a human endeavour: Fungal cells can save lives'. Page 132

Check your Student obook pro for these digital resources and more:

Quizlet

Play a Quizlet game to test your knowledge.

Chapter quiz

Test your understanding of this chapter with the chapter review quiz.

CHAPTER

7

SURVIVING

7.1

Systems are made up of cells, tissues and organs

- Explain the relationship between cells, tissues, organs and body systems.

7.2

The digestive system breaks down food

- Identify the main organs of the digestive system.
- Contrast physical and chemical digestion.

7.3

The digestive system varies between animals

- Describe why there are differences in the digestive systems of different animals.
- Compare the structure of organs in the digestive system to their functions.

7.4

Sometimes things go wrong with the digestive system

- Describe common malfunctions of the digestive system.

7.5

The respiratory system exchanges gases

- Name and describe the key organs and structures of the respiratory system.
- Demonstrate controlled dissection skills.

7.6

Sometimes things go wrong with the respiratory system

- Describe common malfunctions of the respiratory system.

7.7

The circulatory system carries substances around the body

- Name and describe the key organs and structures of the circulatory system.
- Name the components of blood and describe their functions.

7.8

Sometimes things go wrong with the circulatory system

- Describe common malfunctions of the circulatory system.

7.9

The excretory system removes waste

- Identify the key organs and structures of the excretory system.
- Describe the functions of the key organs and structures of the excretory system.

7.10

Science as a human endeavour: Organs can be transplanted

- Recognise and discuss ethical issues associated with organ transplantation.

7.11

Plants have tissues and organs

- Name and describe the structure and function of major plant organs and tissues.
- Explain the role of stomata in photosynthesis.

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

Learning intentions

By the end of this topic, you will be able to:

- explain the relationship between cells, tissues, organs and body systems.

Key ideas

- Anatomists study how the body works.
- 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.

The first anatomists

Evidence of the very first anatomists can be found in the X-ray paintings at Burrunggui on the lands of the Gun-djeihmi people in Kakadu National Park. These diagrams of internal body parts were painted over 8000 years ago. They show the different parts of the skeleton and the circulatory system of the painted person (Figure 1).

Other First Nations peoples' paintings at Injaluk Hill show that the Kunwinjku people of West Arnhem Land were able to identify the internal organs and skeletons of birds, fish and mammals. These paintings were made over 6000 years before the Egyptians removed organs during the mummification process.

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 over 500 years ago through life drawing (drawing people standing in front of him) and by attending public dissections that were held by 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. These groups of cells are called tissues. There are four types of tissue with different functions.

Connective tissue includes blood cells, fat cells, bone cells, tendons and ligaments. These cells are all surrounded by a non-living material called a matrix. The matrix can be solid or liquid. For example, cells in 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, muscle cells in the heart enable it to beat, and muscle cells connected to the skeleton enable us to move.

Figure 1 Internal parts of the body depicted in rock paintings at Burrunggui (Nourlangie) Kakadu 8000 years ago.

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

organ
a group of tissues that work together for a purpose

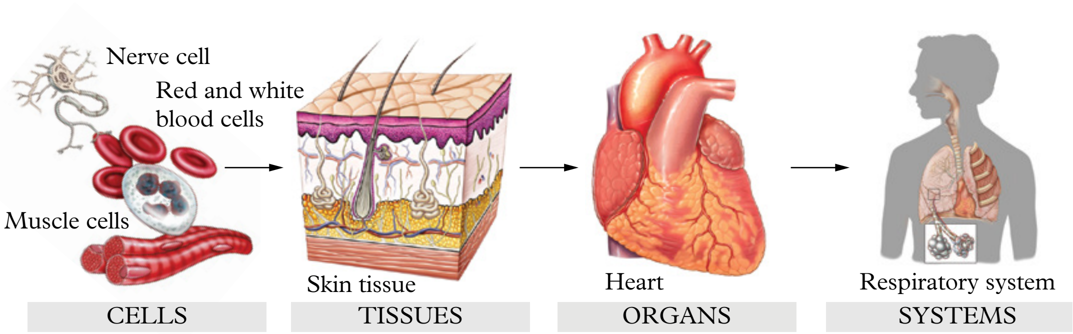


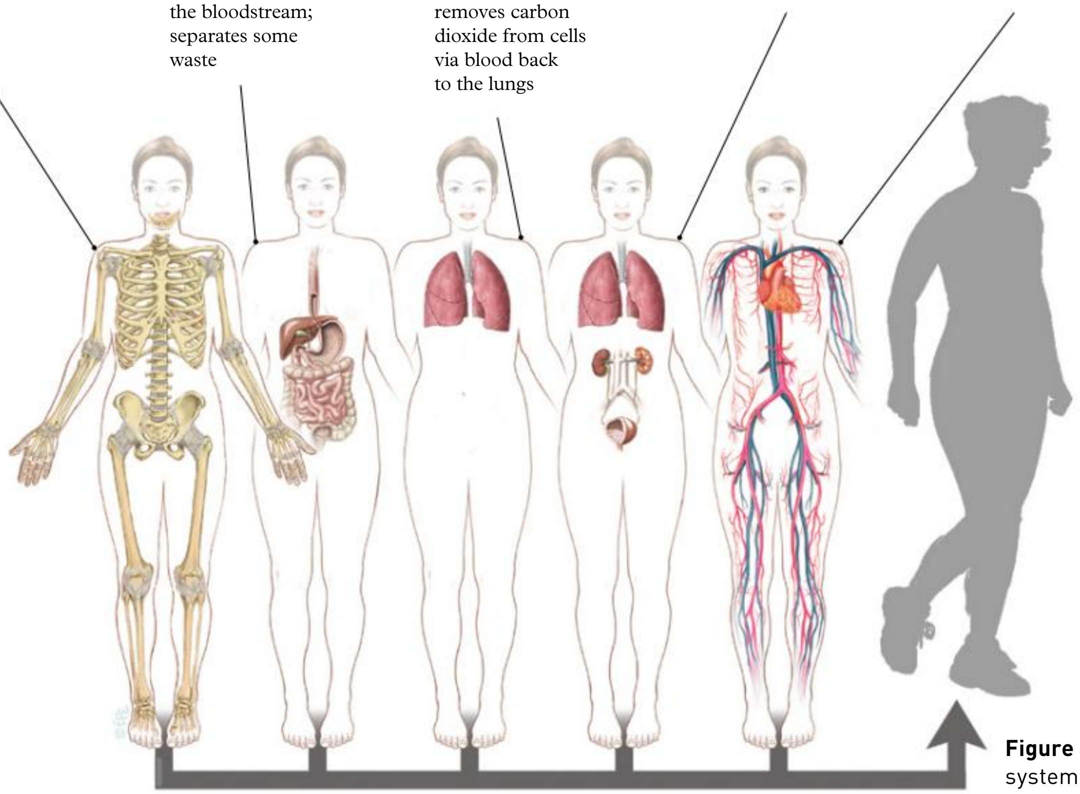
Figure 2 The different levels of organisation in the body

SKILLS LAB

7.1A: Dissecting a chicken wing
Go to page **218**.

CHALLENGE

7.1B: Brown paper body brainstorm
Go to page **220**.



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. Epithelial tissues cover the outside and inside surfaces of the body and help protect the internal parts of the body from damage, bacteria and water loss.

Organs and systems

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 (Figure 3).

system
a group of organs that work together for a purpose

7.1 Check your learning

Retrieve

1 **Define** the terms 'tissue', 'organ' and 'system'.

2 **Recall** the age of the X-ray paintings at Burrunggui.

Comprehend

3 **Explain** how cells, tissues, organs and systems are linked.

4 Use Figure 3 to **explain** how the circulatory system and digestive system work together.

Analyse

5 **Infer** why surgeons need a thorough understanding of anatomy.

6 Select an organ and **examine** how the four types of tissue work together so that the organ can function.

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

7.2 The digestive system breaks down food

Learning intentions

By the end of this topic, you will be able to:

- identify the main organs of the digestive system
- contrast physical and chemical digestion.

Key ideas

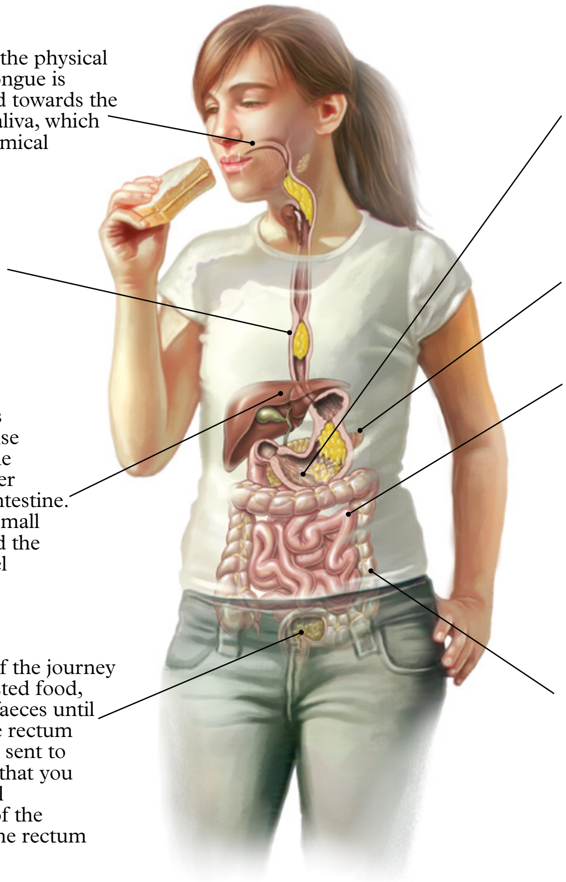
- Digestion is the process of breaking down food so that it can be used by the body.
- Physical digestion occurs when the body manually breaks apart food particles.
- Chemical digestion occurs when enzyme molecules break the chemical bonds in food.
- Nutrients are absorbed in the intestines.

Digested food and drink provide us with energy to live and the materials for our bodies to grow and repair.

The digestive system

Your digestive system is made up of the digestive tract and other organs, including the liver, the gall bladder and the pancreas. The digestive tract is a long tube that starts at your mouth and ends at your anus. It includes the oesophagus, stomach, small and large intestines and the rectum. The digestive tract and organs work together to break down the food you eat and liquid you drink so that it can be absorbed into your blood for transport to your cells. Food that is not needed by the body (such as fibre) stays in the digestive tract until it reaches the rectum. From there, it is released into the toilet through the anus as faeces. This process is called **digestion**. Figure 1 shows the structure of the digestive system and explains the way each part works.

digestion
the process of breaking down food into nutrients



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 1 The structure of the digestive system with key parts labelled

EXPERIMENT
7.2A: Digesting protein
Go to page 221.

EXPERIMENT
7.2B: What if an enzyme was boiled?
Go to page 222.

Physical digestion

Physical digestion starts in your mouth (Figure 2). 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. Your tongue, a large muscular organ can push your food upwards, sideways and backwards towards your teeth.

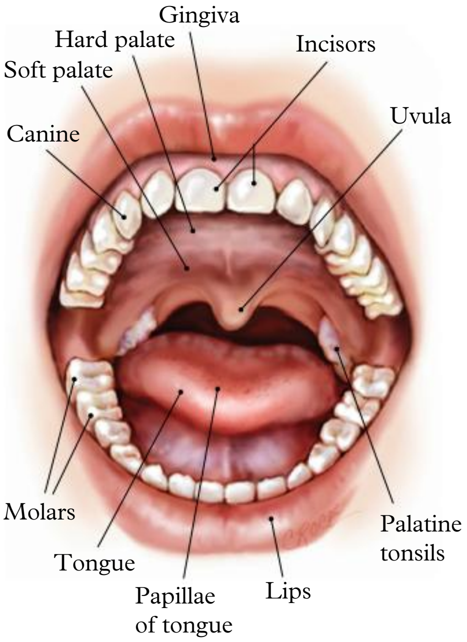


Figure 2 The teeth and mouth physically break down food.

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

Chemical digestion also starts in your mouth (Figure 3). The saliva in your mouth is mostly water, but it 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**.

Absorbing nutrients

Most nutrients from food are absorbed in the small intestine. The small intestine is narrow but quite long at around 5 metres. The inside of the small intestine is full of ridges called **villi**. Villi increase the surface area of the small intestine. The large surface area of the small intestine means that there is a lot of space for nutrients to pass over and opportunity for the most number of nutrients to be absorbed.

Figure 3 Biscuits are physically digested by teeth and chemically digested by enzymes in saliva.

peristalsis
the process of swallowed food being moved along the digestive tract by a wave of contractions

chyme
a mixture of acid, enzymes and digested food that leaves the stomach

villi
small ridges in the small intestine that absorb nutrients from chyme

7.2 Check your learning

Retrieve

1 **Recall**, in order, the organs of the digestive system that food moves through, from the mouth to the anus.

2 **Name** the organs that are involved in digestion but do not have food passing through them.

Comprehend

3 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.

4 **Explain** how saliva makes it easier to eat dry biscuits.

5 **Explain** the advantage of the intestine having villi.

Analyse

6 **Contrast** (the differences between) mechanical and chemical digestion.

7 **Contrast** (the differences between) the digestive system and the digestive tract.

Apply

8 **Propose** some tools that could work the same way as incisors, canines and molars.

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

7.3 The digestive system varies between animals

Learning intentions

By the end of this topic, you will be able to:

- describe why there are differences in the digestive systems of different animals
- compare the structure of organs in the digestive system to their functions.

Key ideas

- Carnivores are organisms that eat meat.
- Herbivores are organisms that eat plant material.
- Omnivores, including humans, eat a variety of foods.
- The structure of the digestive system can be used to predict the type of food an animal eats.

caecum
a small dead-end pouch that connects the small and large intestines

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 specific function. Incisors have a sharp knife-like 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 carnivores (meat eaters) have large canine teeth. Molars are flatter and are especially good at grinding plant food 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 a fossilised animal ate when it was alive (Figure 1).

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 – physically or chemically.

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 (Figure 2). This is a problem for the animal as it means the plant matter is digested after it passes through the small intestine where nutrients are absorbed. 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.

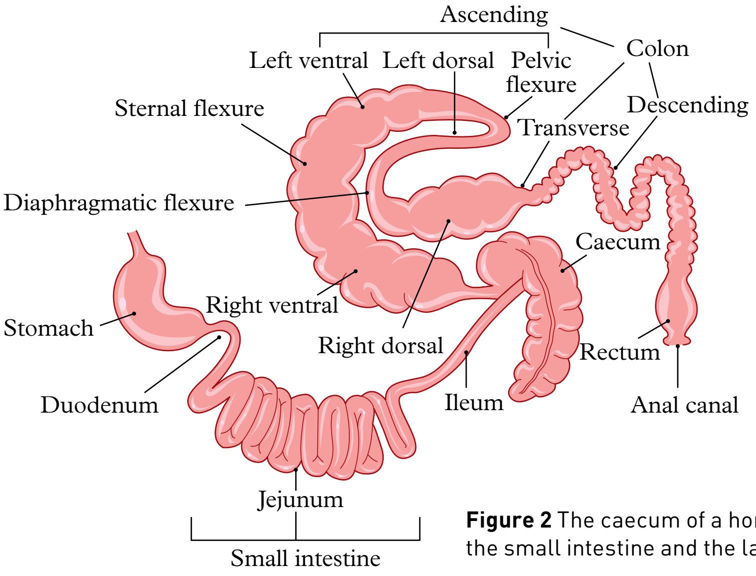


Figure 2 The caecum of a horse is found between the small intestine and the large intestine.

Ruminants

Ruminants are animals with hooves that have four chambers in their stomachs. A cow is an example of a ruminant (Figure 3). 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 acid and enzymes, just like a human stomach.

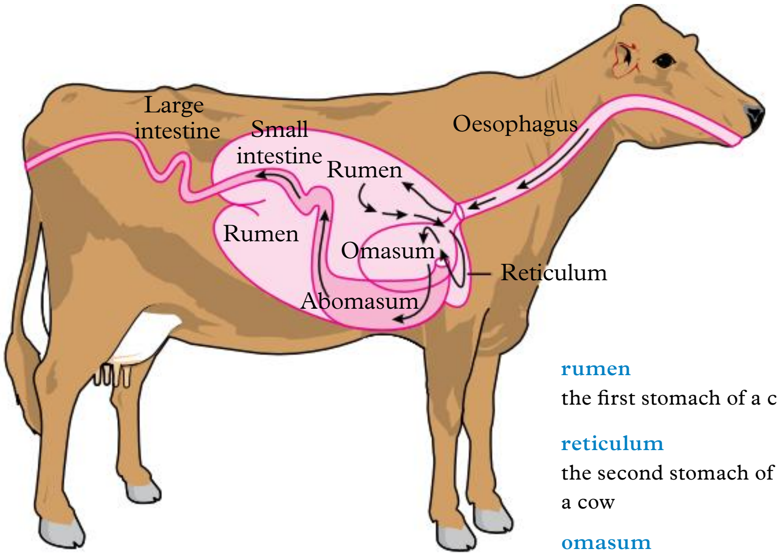


Figure 3 The four stomachs of a cow allow it to digest grass.

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

Retrieve

1 **Recall** why some animals eat their own faeces.

Comprehend

2 **Describe** two ways the structure of the digestive system in animals can be different.

3 **Explain** the function of each of the four stomachs found in a cow.

Analyse

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.

Apply

6 **Investigate** the digestive system of an animal of your choice. **Compare** (the similarities and differences between) your selected digestive system and the digestive system of humans. **Explain** how the structure of your animal's digestive system allows it to digest the food it eats.

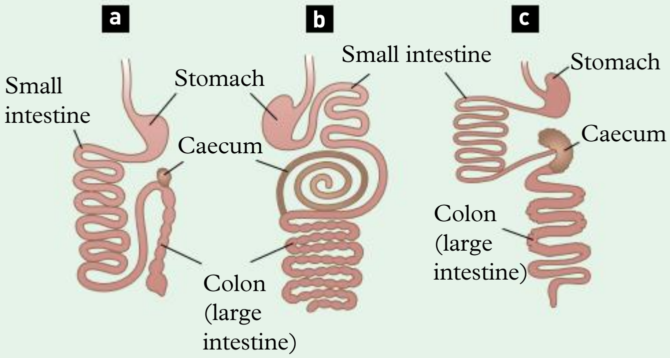


Figure 4 Digestive systems of three animals with different diets

Figure 5 Photographs of fossils

Quiz me

Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

7.4 Sometimes things go wrong with the digestive system

Learning intentions

By the end of this topic, you will be able to:

- describe common malfunctions of the digestive system.

Key ideas

- Stomach ulcers are caused by the bacterium *Helicobacter pylori*.
- Gallstones stop bile leaving the gall bladder.
- People who do not have the enzymes to break down gluten have gluten intolerance.
- Constipation is a blockage in the large intestine.

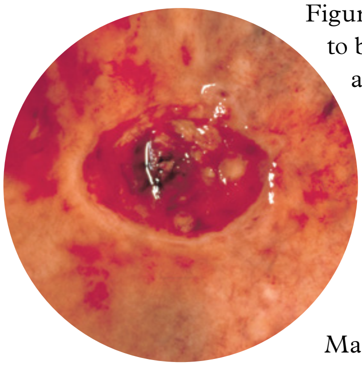


Figure 1 A stomach ulcer

ulcer	an open sore on the inside or outside of the body
gallstone	a hard substance or stone that is produced by the gall bladder
ultrasound	a way sound can be used to identify tissue or to shatter stones

Stomach ulcers

For many years, **ulcers** (small open sores, Figure 1) 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 acidic environment, no one considered that bacteria could be the cause of the ulcers.

Two Australian scientists, Barry Marshall and Robin Warren (Figure 2), 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 (Figure 3). 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 3 Gallstones

Gluten intolerance

Gluten is a small molecule found in many cereals and grains (Figure 4). 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 that they cannot digest the gluten and that they are **gluten intolerant**. Gluten intolerance can cause a range of different symptoms, from blockages of the intestines to **diarrhoea** (watery faeces). Gluten intolerance is not an allergy. If a person is allergic to gluten, their body's immune system fights against the gluten. This can affect their whole body, not just the digestive system.

Figure 4 A number of grains contain gluten.

gluten intolerant unable to digest gluten

diarrhoea watery faeces

Constipation

Sometimes the large intestine becomes blocked. This can be caused by diet (not eating enough fibre such as 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 (Figure 5). Sometimes medication is needed to help the large intestine move the blockage. If it is not treated, the person may die.

Figure 5 Constipation may cause pain and discomfort.

7.4 Check your learning

Retrieve

1 **Recall** what causes stomach ulcers and how they can be treated.

Comprehend

2 **Explain** what causes the pain that occurs with a stomach ulcer.

3 **Describe** a possible solution for constipation.

Analyse

4 **Compare** (the similarities and differences between) gallstones and gluten intolerance.

5 **Identify** one thing that all the malfunctions discussed in this topic have in common.

Apply

6 **Create** a flow chart summarising what happens when and after gallstones form.

7 Jarrah often has a sore stomach. Sometimes, he needs to leave class in a hurry to go to the toilet. Trung notices that Jarrah often leaves classes that happen after lunch. **Propose** two possible causes for Jarrah's pain. **Explain** why this pain might become worse after eating. **Decide** which of these two reasons might be the likely cause of the pain and justify your answer.

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

7.5 The respiratory system exchanges gases

Learning intentions

By the end of this topic, you will be able to:

- name and describe the key organs and structures of the respiratory system
- demonstrate controlled dissection skills.

Video 7.5
The respiratory system

Interactive 7.5
The respiratory system

Key ideas

- 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.

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. Oxygen is needed to release energy from glucose.

This process is called **cellular respiration**. It 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 cells need 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.

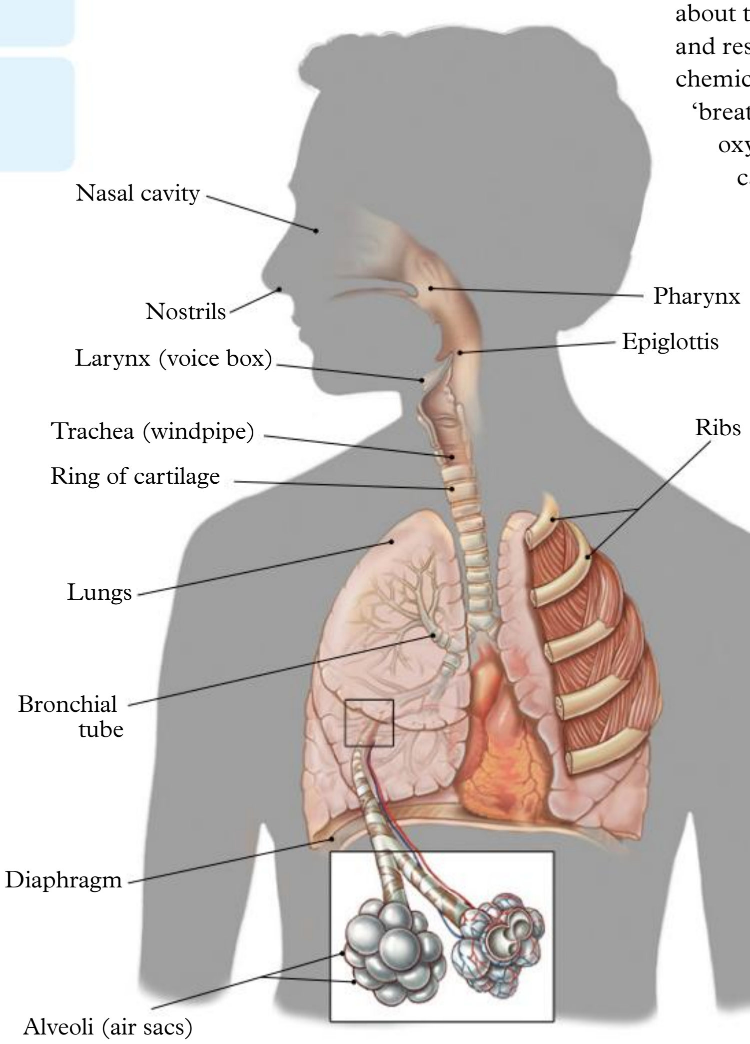


Figure 1 The structure of the respiratory system

Where does the air go?

We breathe air in through our nose and mouth. Any dust and pollens we breathe in are trapped by hairs and wet surfaces as the air 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 **223**.

CHALLENGE

7.5B: Fish dissection
Go to page **224**.

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 (Figure 2).

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 Year 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.

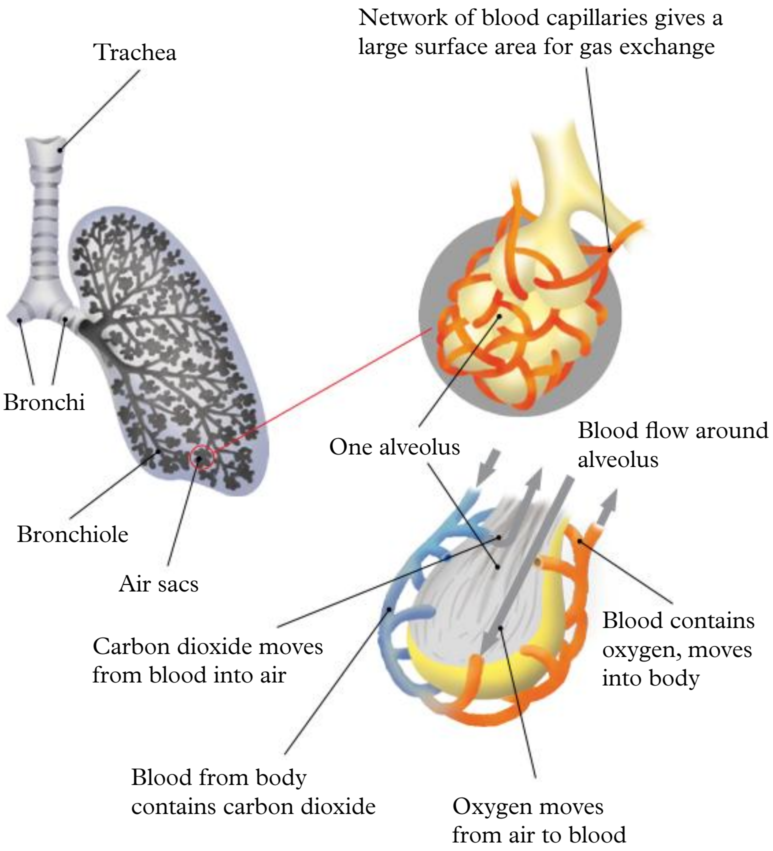


Figure 2 Gas exchange takes place in the alveoli.

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.

7.5 Check your learning

Retrieve

1 **Define** the term 'gas exchange'.

2 Gases constantly move in and out of the blood into the lungs. **Identify** the gases that move in and out of the respiratory system.

3 **Recall** the role that the epiglottis plays in the respiratory system.

Comprehend

4 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.

5 **Describe** the sequence of steps in breathing in and breathing out.

6 **Explain** the advantage that the large surface area of the alveoli gives to oxygen needing to pass into the blood.

Apply

7 **Discuss** why we need to breathe.

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

cellular respiration
the chemical reaction between glucose and oxygen that produces 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

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

7.6

Sometimes things go wrong with the respiratory system

Learning intentions

By the end of this topic, you will be able to:

- describe common malfunctions of the respiratory system.

Key ideas

- 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 matter. 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 (Figure 1). 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.

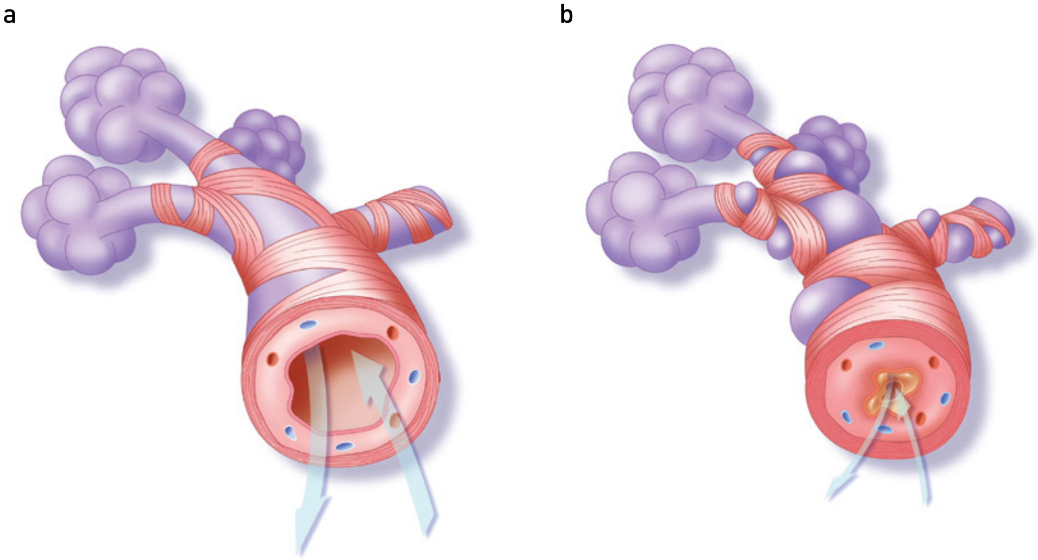


Figure 2 Asthma causes the bronchioles to become narrow: **a** normal airway and **b** asthmatic airway.

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 (Figure 2). When this happens, it is hard to breathe. Asthma attacks can be reversed by drugs, such as Ventolin, that relax and open the airways (Figure 3).

Figure 3 Ventolin is commonly used to control asthma attacks (blue). It can be inhaled through the mouth and nose. Other drugs help prevent asthma (red).

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 viral growth in the lungs

Emphysema

Smoking involves breathing toxic chemicals and tar into your lungs (Figure 4). The tar is thick and sticky like honey, covering the inside of the alveoli and stopping oxygen from moving into the blood. The toxic chemicals 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.

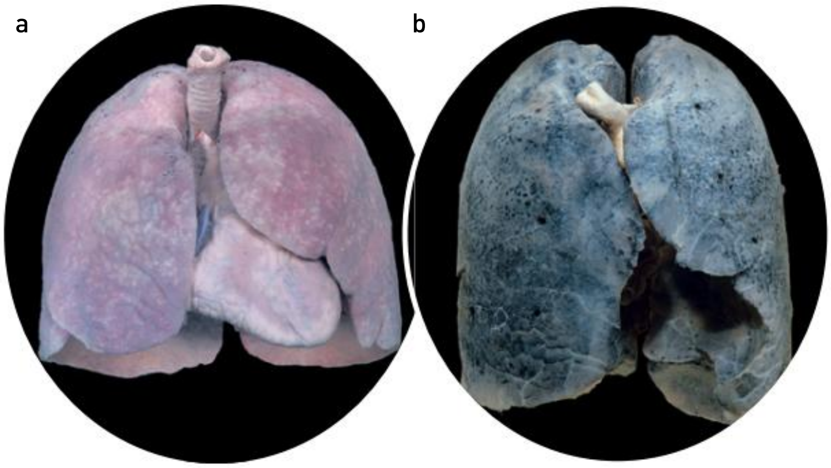


Figure 4 a Healthy lungs **b** A smoker's lungs

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 (drugs that kill bacteria) can clear the lungs again, allowing the person to breathe.

7.6 Check your learning

Retrieve

1 **Recall** the cause for each of the following:
  - **a** a cough
  - **b** a sneeze.

Comprehend

2 **Describe** what happens in the lungs during an asthma attack.

3 **Describe** one health risk people take with their lungs and the consequences of this risk.

Analyse

4 **Contrast** (the differences between) the changes in the lung for emphysema and pneumonia.

5 **Infer** why people with pneumonia feel tired all the time.

Apply

6 **Investigate** why it is physically impossible to keep your eyes open during a sneeze.

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

7.7

The circulatory system carries substances around the body

Learning intentions

By the end of this topic, you will be able to:

- name and describe the key organs and structures of the circulatory system
- name the components of blood and describe their functions.

Video 7.7A
The circulatory system

Video 7.7B
Heart dissection

Interactive 7.7
The circulatory system

Key ideas

- 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.

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 right 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 (Figure 2). 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. 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.

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

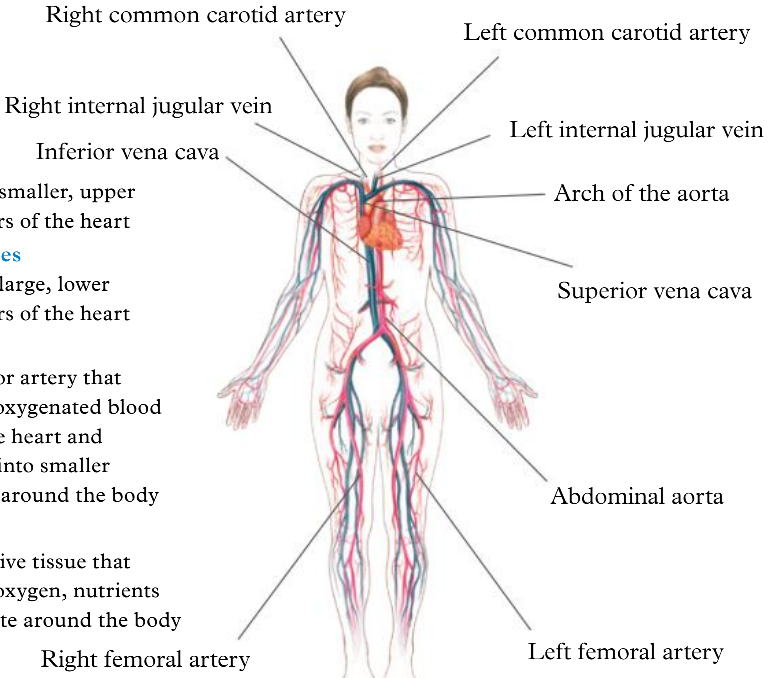


Figure 1 The structure of the circulatory system with key parts labelled

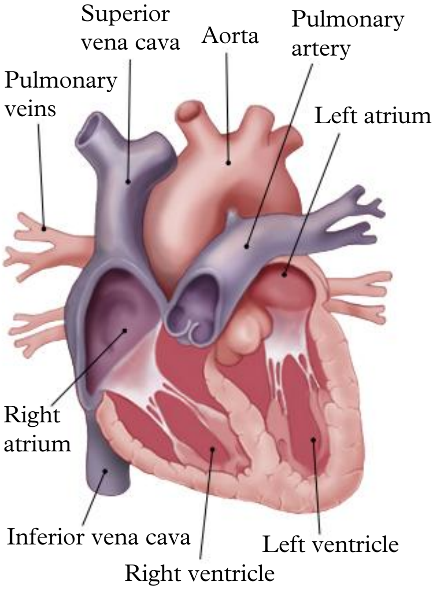


Figure 2 This diagram shows your heart, as well as some of the major blood vessels that travel to and from the heart. The diagram uses a common convention that shows the veins in red and the arteries in blue.

EXPERIMENT

7.7: Heart dissection
Go to page **225**.

- 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 (Figure 3). 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 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 connect the arteries and veins. They are sometimes referred to as a capillary bed when they are in large numbers surrounding an organ (Figure 4).

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 hydra (1–2 mm long) spend life surrounded by water. They do not have a heart or blood vessels. Instead gases diffuse in and 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 the fluid 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.

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

arteriole
smaller artery

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

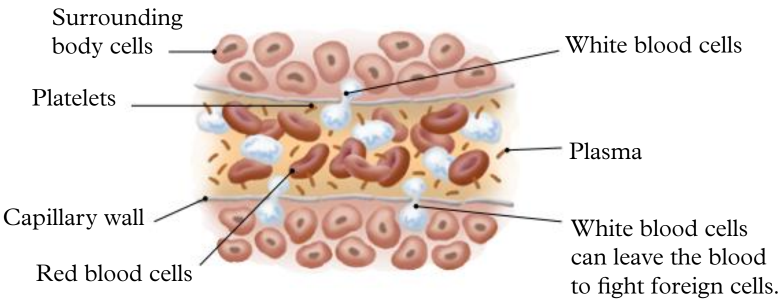


Figure 3 A cross-section of a blood vessel

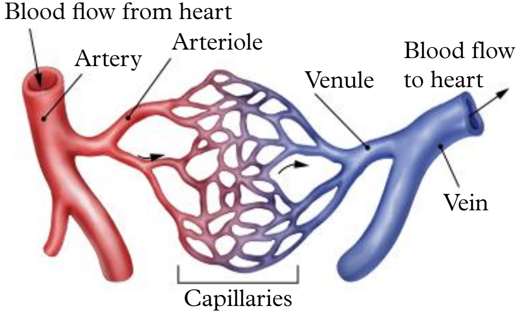


Figure 4 A capillary bed, showing the relationship between arteries, veins and capillaries

7.7 Check your learning

Retrieve

1 **Recall** the function of red blood cells, white blood cells and platelets.

Comprehend

2 Use diagrams to **illustrate** 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.

Analyse

5 **Identify** the body system that supplies the nutrients that the circulatory system moves around the body.

Apply

6 Instead of the blood travelling directly from the lungs to the rest of the body, the blood returns to the heart first. **Discuss** one advantage of the blood returning to the heart before moving around the body.

Quiz me
Complete the Quiz me to check how well you’ve mastered the learning intentions and to be assigned a worksheet at your level.

7.8 Sometimes things go wrong with the circulatory system

Learning intentions

By the end of this topic, you will be able to:

- describe common malfunctions of the circulatory system.

Key ideas

- 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.

Valve disease

The heart has a series of valves that prevent the blood from flowing backwards (Figure 1). 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 (Figure 2). 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.

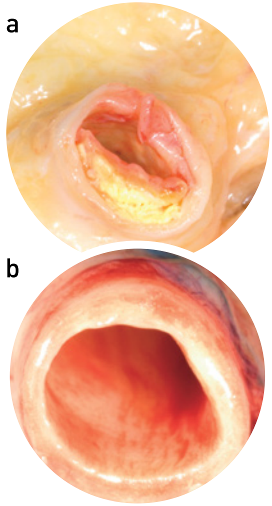


Figure 2 a A blocked artery and **b** an unblocked artery

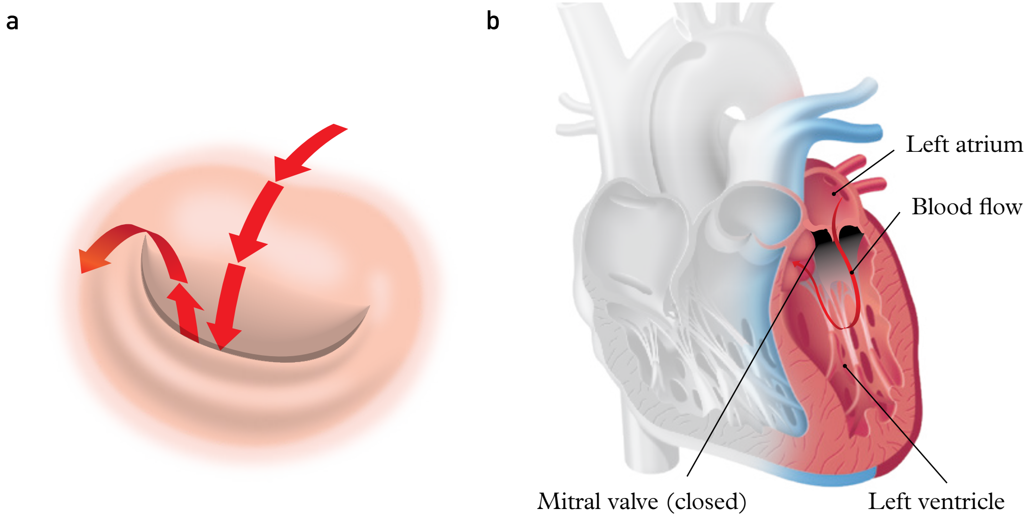


Figure 1 a The heart valve opens to allow blood to flow from the atrium to the ventricle. **b** Closing of the valve prevents the backflow of blood so that it can be pumped effectively around the body.

CHALLENGE
7.8: Modelling blood flow
Go to page **226**.

Coronary heart disease

A heart attack is usually caused by coronary heart disease, which is 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 (Figure 3).

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.

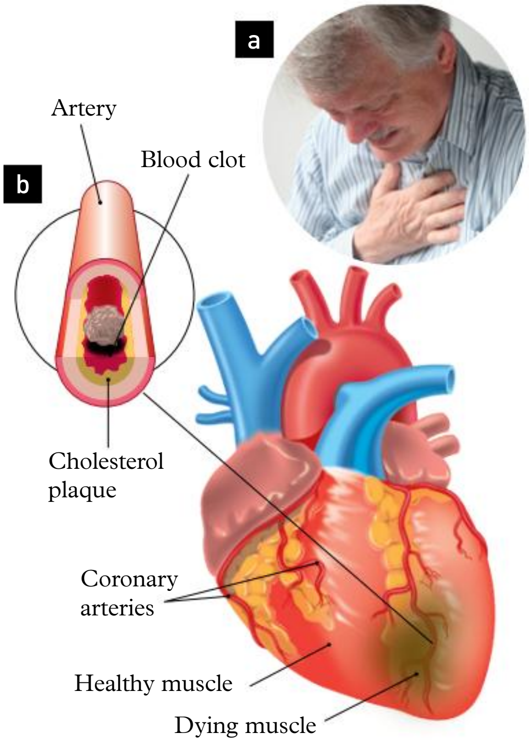


Figure 3 a Chest pain is often caused by **b** a blockage in the heart’s own blood vessels.

The heart is a muscle and, like all muscles, it needs exercise to keep it strong. Regular exercise is all it needs (Figure 4). In people who are overweight or who smoke cigarettes, the heart needs to work much harder to do the same job. This is 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.

Figure 4 Exercise can help keep the heart healthy and strong.

Pericarditis

The pericardium is the thin sac that surrounds the heart and helps it move easily when it beats (Figure 5). 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.

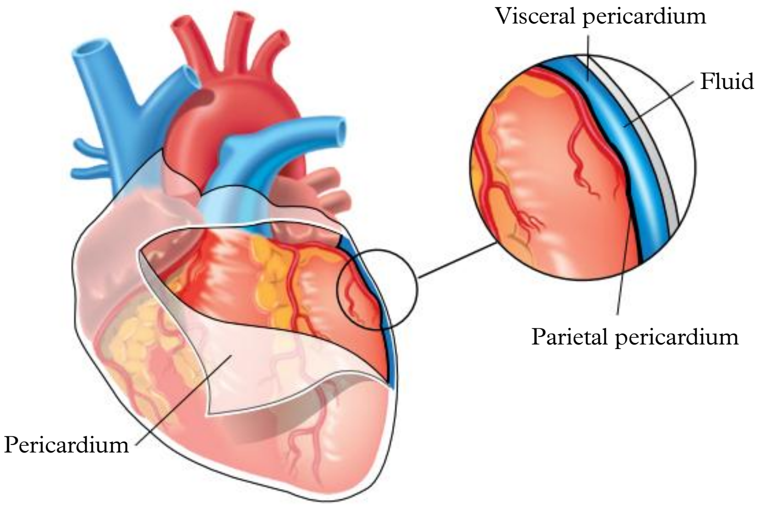


Figure 5 The pericardium reduces friction in a beating heart.

7. 8 Check your learning

Retrieve

1 **Identify** what causes the ‘lub-dub’ sound you hear when you listen to your heart.

2 **Recall** the cause of the following valve conditions:

  a stenosis

  b regurgitation or insufficiency

  c prolapse.

3 **Recall** the function of the pericardium sac that surrounds the heart.

4 **Identify** two things you could do to ensure your circulatory system stays healthy.

Comprehend

5 **Explain** the link between atherosclerosis and coronary heart disease.

6 **Explain** 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.

Quiz me
Complete the Quiz me to check how well you’ve mastered the learning intentions and to be assigned a worksheet at your level.

EXPERIMENT

7.9: Kidney dissection
Go to page **227**.

7.9 The excretory system removes waste

Learning intentions

By the end of this topic, you will be able to:

- identify the key organs and structures of the excretory system
- describe the functions of the key organs and structures of the excretory system.

Key ideas

- The liver helps rid the body of nitrogen.
- The kidneys filter blood to remove waste which is excreted as urine.
- Sweating releases waste products from the body through the skin.

Our cells and our bodies create waste products that need to be removed. The process of removing wastes is called excretion. The organs of the excretory system are the kidneys, liver, lungs and skin (Figure 1).

All of the nutrients that are carried through the body by the circulatory system are used by cells. Cells undergo a series of chemical reactions called **metabolism**. Some of the chemical products produced during metabolism are toxic and need to be excreted (removed) from the body. Water is also important for controlling wastes because it can dilute harmful substances and their effects. Water also moves substances quickly and is essential for keeping our body temperature just right.

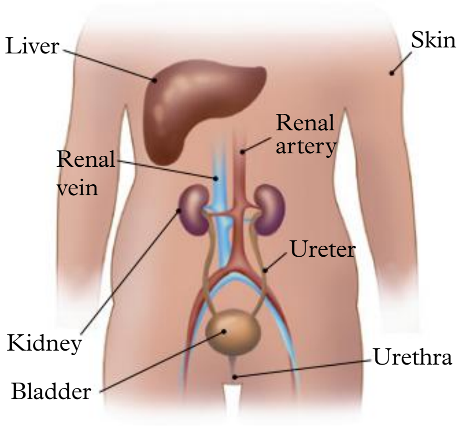


Figure 1 The structure of the excretory system with key parts labelled

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 in the body and removed in urine

nephron
a tiny structure in the kidneys that filters the blood

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**. The body cannot store the amino acids that it doesn't use immediately. Your liver breaks down these amino acids (and many other chemicals) into 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.

Interactive 7.9A
The excretory system

Interactive 7.9B
The skin

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 which is recirculated around the body and urine which is excreted from the body.

The skin

The skin is the largest organ in the excretory system. The skin releases sweat which contains waste products such as heat, salts and urea. If you lick your upper lip after exercise, you will taste the salt in your sweat.

7.9 Check your learning

Retrieve

1 **Recall** how waste products in the body are created.

2 **Name** the three organs of the excretory system.

Comprehend

3 **Explain** how the liver and kidneys work together.

Apply

4 **Predict** the consequences of not drinking enough water. State how you would feel and explain why.

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

//SCIENCE AS A HUMAN ENDEAVOUR//

7.10 Organs can be transplanted

Learning intentions

By the end of this topic, you will be able to:

- recognise and discuss ethical issues associated with organ transplantation.

In this chapter, you have learnt that sometimes things go wrong with body systems. Treatments are available to treat many of the malfunctions, but sometimes these treatments do not improve a person's condition enough. In these cases, cell, tissue or organ transplantation might be considered.

Organ transplantation

During an organ transplant, a diseased organ is taken from a person's body and replaced with a healthy organ from another person's body. The person receiving the organ is called the **recipient** and the person giving the organ is called the **donor**. The heart, lungs, kidneys, liver, stomach, pancreas and intestines can all be transplanted.

Ethical issues

Organ transplantation can be an effective solution to a serious problem, but it can challenge people's ethics. **Ethics** is the series of rules that determines what is right and what is wrong. Ethical issues associated with organ transplantation can arise at many different stages of the transplantation process, and they can involve recipients, donors, families and medical practitioners.

There are more people waiting to receive donated organs than there are organs available. Many people on the waiting list will not survive unless they receive a transplant. In line with ethical principles, the decision to offer one of these people an organ must not be affected by the potential recipient's race, religion, gender, social status, disability or age. Instead, the decision relies on how well the organ matches the recipient, how long the person has been waiting for a transplant, how urgent the transplant is, whether a good outcome is likely, and whether the organ can be made available to the person in time.

Most commonly, organs are donated by people who are brain dead. This means that their brain is no longer able to keep their hearts and lungs functioning. Many people decide to offer their organs for donation before they become ill or have an accident and record this wish with the Australian Organ Donor Register. When a person dies, however, the family of the donor must also give their permission for organs to be removed. Ethical issues arise when the donor's family disagrees with the donor's wishes.

Kidneys and pieces of liver can be donated by living people. Ethical issues raised by living donation are explored in this topic's Test your skills and capabilities box.

recipient
the person receiving a donated organ

donor
the person giving an organ; usually deceased, sometimes living

ethics
the series of rules that determines what is right and what is wrong

7.10 Test your skills and capabilities

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 child to put themselves at risk by donating the 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 that can affect the way they move for several weeks.

1 **Explain** why the potential donor may want to donate their kidney.
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 child to donate a kidney.
4 The recipient of the donated organ wants to give a gift to the potential donor.
Explain why this could be described as selling the organ. **Consider** whether selling the organ is right or wrong.
5 **Evaluate** if 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 1 When kidneys are unable to clean the blood, patients need to spend 6 hours a day, 3 times a week in dialysis.

CHALLENGE

7.11A: Locating the stomata of a leaf
Go to page **228**.

CHALLENGE

7.11B: Locating the xylem and phloem in a stem
Go to page **229**.

7.11

Plants have tissues and organs

Learning intentions

By the end of this topic, you will be able to:

- name and describe the structure and function of major plant organs and tissues
- explain the role of stomata in photosynthesis.

root	a plant organ involved in absorbing nutrients and water
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 a plant
vascular bundle	a group of tubes in plant stems that carry water and nutrients around the plant

Key ideas

- Plants are multicellular organisms that have specialised organs to help move water and nutrients around the plant.
- Roots use osmosis to absorb water from the soil.
- Stems transport water and nutrients around the plant.
- Leaves exchange gases and produce the sugars needed for energy.

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** (Figure 1).

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.

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.

Figure 2 shows the structure of a plant stem.

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) (Figure 3).

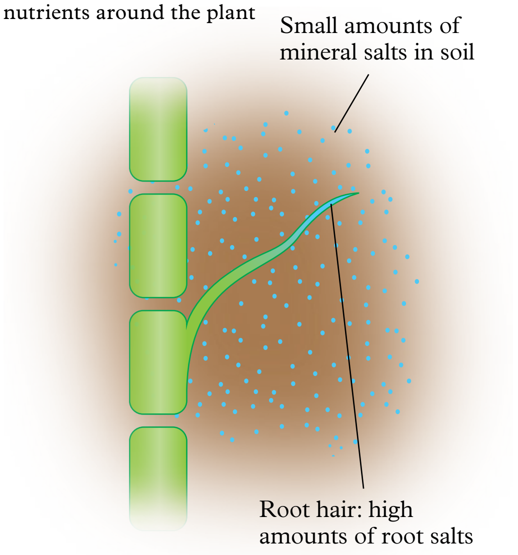


Figure 1 Water moves into the root hair by osmosis.

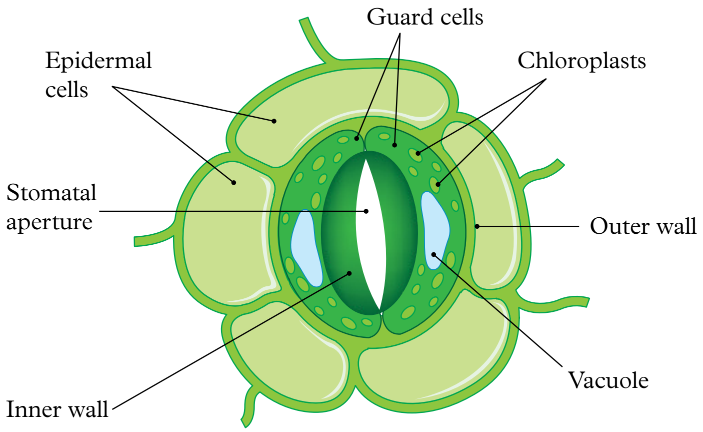


Figure 3 The structure of a plant stoma

CHALLENGE

7.11C: Modelling root cells
Go to page **230**.

EXPERIMENT

7.11D: Factors that affect transpiration
Go to page **231**.

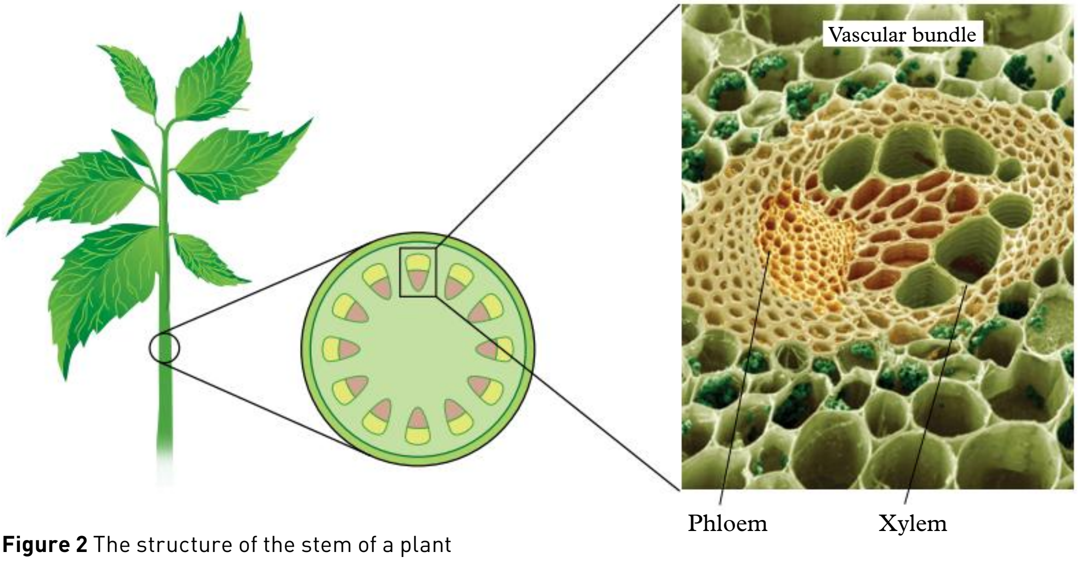


Figure 2 The structure of the stem of a plant

A plant stoma has two specialised guard cells 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).

Figure 4 Autumn leaves come in a range of colours.

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

chlorophyll
a green pigment in chloroplasts that absorbs solar energy, which is used by plants in photosynthesis

Figure 5 Artificially coloured orchids

7.11 Check your learning

Retrieve

1 **Define** the term 'osmosis'.

Comprehend

2 **Name** three organs found in most plants and **describe** their function (what they do).

3 **Explain** the role of stomata in photosynthesis.

Analyse

4 **Contrast** (the differences between) xylem and phloem.

5 **Identify** the system in humans that provides the same function as a plant stem.

Apply

6 Some florists sell blue orchids that are artificially coloured by putting white orchids in blue water (Figure 5). Use your knowledge of plant systems to **determine** how these orchids may have become blue.

Quiz me
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

CHAPTER 7 REVIEW

SURVIVING

Retrieve

1 **Recall** where chemical digestion occurs in the body.

2 **Identify** the disease that is caused by a build-up of plaque.
  - A pneumonia
  - B valve disease
  - C atherosclerosis
  - D asthma

3 **Recall** which body system removes wastes.
  - A respiratory system
  - B circulatory system
  - C digestive system
  - D excretory system

4 **Name** the gaseous waste product removed by the lungs.

5 **Identify** four things that the circulatory system transports around your body.

6 **Recall** where photosynthesis occurs in a plant.
  - A leaf
  - B stem
  - C root
  - D xylem

Comprehend

7 **Describe** the function of each of the four types of tissue.

8 a **Identify** where peristalsis occurs in the body.
  b **Explain** how it causes food to move.

9 **Explain** how the human digestive system can ‘feed’ all the other systems.

10 **Describe** how the respiratory system and circulatory system work together.

11 **Explain** why muscles need more blood during exercise.

12 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.

13 **Describe** what is meant by an ‘ethical issue’.

Analyse

14 **Contrast** organ and system.

15 **Contrast** cellular respiration and breathing.

16 Plants do not have a digestive system. **Identify** which organ helps the plant supply all its energy needs.

17 **Infer** why you would not expect to find chloroplasts in the roots of a plant.

Apply

18 **Propose** a possible motivation for the earliest studies of the human body.

Critical and creative thinking

19 Sweating is often considered to be a bad thing. **Evaluate** this statement (by describing why people sweat, what is in the sweat, what would happen if a person was unable to sweat and deciding if the statement is correct).

20 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. **Determine** the human system that this represents in the plant. Identify which organ(s) has the same function in humans.

21 Human dissections have always been used to teach medical students anatomy, but they are less common now than in the past. In many cases, real dissection has been replaced with computer animations and models. **Propose** why human dissection is important.

22 Imagine it is your job to **develop** 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.

23 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 1 to help you get started.

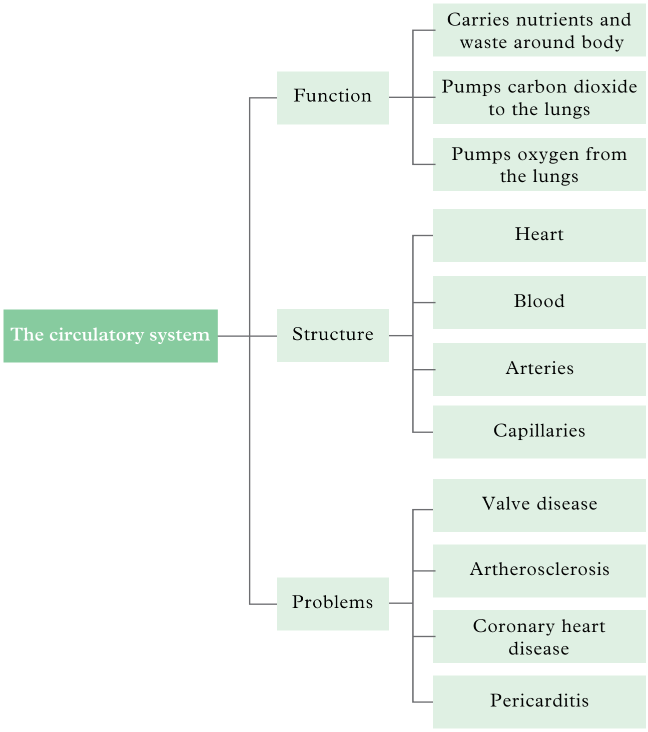


Figure 1 A concept map of the circulatory system

24 Presenting data to an audience can take many forms. An increasingly common way to present important information is in 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. An example is given in Figure 2.

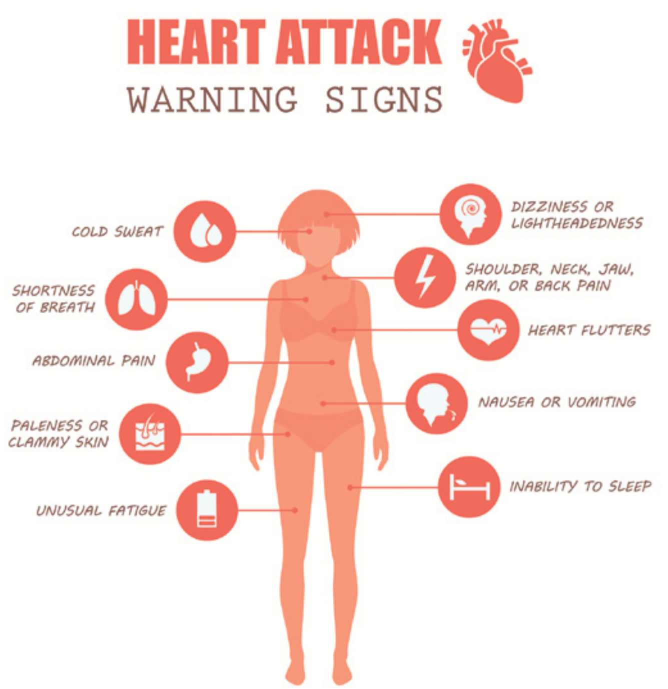


Figure 2 An infographic about heart attack warning signs

Select one of the complications of the digestive system and plan an infographic that will pass the important information on to an audience.

- **a** **Consider** why you are making the infographic. Is it to pass on information, or to get people to change their habits?
- **b** **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?
- **c** **Propose** how the change in the digestive system causes the symptoms.
- **d** **Identify** what people who have the symptoms should do. Should they look out for symptoms, change their diet or see a doctor?
- **e** **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.
- **f** 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?

25 Revisit Challenge 7.1B, 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 major body systems has changed since completing this unit. Give yourself a score out of 5 for *then* and a score out of 5 for *now*.

Social and ethical thinking

26 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.

Research

27 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 who are 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.

Figure 3 Smoking is banned in many public areas.

» Artificial organs

When the organs in the body start to fail, their function needs to be replaced. This can be done through organ transplantation from another person, or the replacement of the organ with an artificial version.

- Research an artificial heart that is currently being used by surgeons.
- Describe the materials being used to construct the heart.
- Explain how the artificial heart is able to replace the original organ.
- Write a blog outlining why artificial hearts should be used by surgeons more often.

» 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.

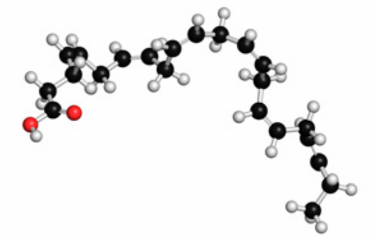


Figure 4 Structure of an omega-3 fatty acid. White represents hydrogen, black carbon and red oxygen.

» Animal testing

Organoids are created when small groups of specialised cells become organised in a flask of nutrients in a lab. These small groups of tissues can be used to mimic almost any organ in the body.

- Describe how the development of organoids could affect the way scientists use animals to test their research.
- Describe the ethics of using organoids. Explain how this might change the way people view scientific research.
- Compare the cost of using live animals against the cost of producing and maintaining organoids.
- Prepare an argument that could be presented to a research centre.

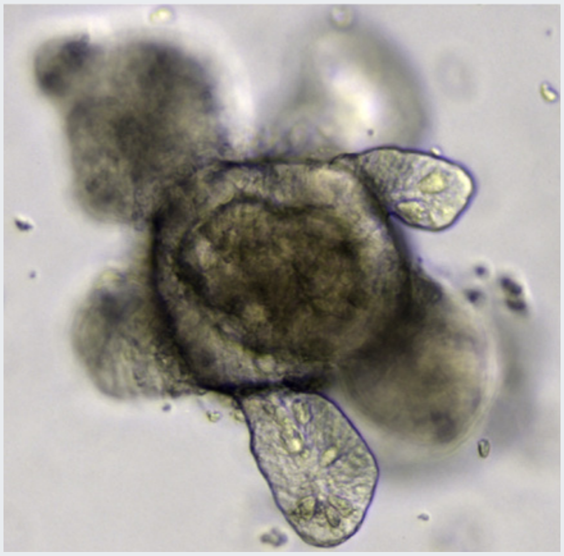


Figure 5 An organoid representing the intestines

Chapter checklist

Now that you have completed this chapter, reflect on your ability to do the following.

	I can do this.	I cannot do this yet.
• Explain 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 140
• Identify the main organs of the digestive system. • Contrast physical and chemical digestion.	☐	☐ Go back to Topic 7.2 'The digestive system breaks down food'. Page 142
• Describe why there are differences in the digestive systems of different animals. • Compare the structure of organs in the digestive system to their functions.	☐	☐ Go back to Topic 7.3 'The digestive system varies between animals'. Page 144
• Describe common malfunctions of the digestive system.	☐	☐ Go back to Topic 7.4 'Sometimes things go wrong with the digestive system'. Page 146
• Name and describe the key organs and structures of the respiratory system. • Demonstrate controlled dissection skills.	☐	☐ Go back to Topic 7.5 'The respiratory system exchanges gases'. Page 148
• Describe common malfunctions of the respiratory system.	☐	☐ Go back to Topic 7.6 'Sometimes things go wrong with the respiratory system'. Page 150
• Name and describe the key organs and structures of the circulatory system. • Name the components of blood and describe their functions.	☐	☐ Go back to Topic 7.7 'The circulatory system carries substances around the body'. Page 152
• Describe common malfunctions of the circulatory system.	☐	☐ Go back to Topic 7.8 'Sometimes things go wrong with the circulatory system'. Page 154
• Identify the key organs and structures of the excretory system. • Describe the functions of the key organs and structures of the excretory system.	☐	☐ Go back to Topic 7.9 'The excretory system removes waste'. Page 156
• Recognise and discuss ethical issues associated with organ transplantation.	☐	☐ Go back to Topic 7.10 'Science as a human endeavour: Organs can be transplanted'. Page 157
• Name and describe the structure and function of major plant organs and tissues. • Explain the role of stomata in photosynthesis.	☐	☐ Go back to Topic 7.11 'Plants have tissues and organs'. Page 158

Check your Student obook pro for these digital resources and more:

Quizlet

Play a Quizlet game to test your knowledge.

Chapter quiz

Test your understanding of this chapter with the chapter review quiz.

CHAPTER

8

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.

1.1A Making a balloon rocket

EXPERIMENT

Aim

To make a balloon rocket.

Materials

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

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 up the balloon and hold the end closed. While holding the end closed, stick the balloon to the straw with the sticky tape, as shown in Figure 1. (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 moves 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.

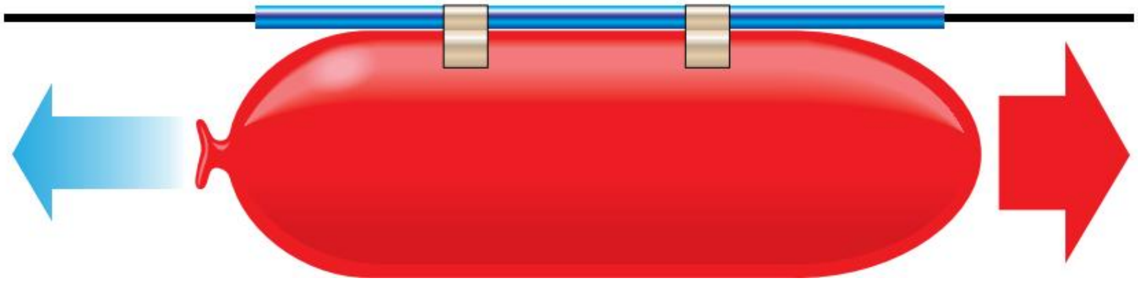


Figure 1 A balloon rocket

1.1B 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 1.1A, 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 inquiry.
    - 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 the results of 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.

1.2 Avoiding errors and improving accuracy

CHALLENGE

Aim

To minimise errors and improve the accuracy of results.

What you need:

Ruler, electronic scales, item from pencil case, analogue clock

What to do:

1 Measure the following line.

Record the value in your logbook.

2 Use the electronic scales to measure the mass of an item from your pencil case (such as a pen). Make four measurements and record them in an appropriate table in your logbook.

3 Working in groups of three, read the time on an analogue clock, with each person reading from a different perspective. One person should read the clock from directly in front of the clock. Another person should stand to the right of the first person at an acute angle. The other person should stand to the left of the first person at an acute angle. Each person should read the clock and note the time.

Discussion

1 Compare your measurement of the line in Step 1 to the person's next to you. Identify any differences in the values you measured. Explain a possible error that might account for differences in measuring with rulers. Describe how you could minimise this error.

2 a Identify any differences in the mass values you measured in Step 2. (Are they closely grouped together?) Explain a possible error that might account for differences in measuring with electronic scales. Describe how you could minimise this error.
  b Calculate the average of the mass measurements. Compare the average measured value with the individual measurements. Describe how the average would be affected by one value that was much lower than the other values.

3 a Describe any differences in the clock time that was read at different positions.
  b Identify the type of error that the differences represent.
  c Describe how this type of error could be avoided.

Figure 1 The materials you'll need for this challenge

1.5 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 in Figure 1.
4. Insert a marshmallow into the ring.
5. Pull back the marshmallow ensuring the rubber bands are horizontal to the ground. Measure the distance from the chair legs you have pulled back the marshmallow (Figure 2).
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 rubber 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 dependent 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 supported.
3. A student claimed that their rubber bands became stretched and less flexible by the end of the experiment. Describe how this could affect the results of the experiment. Describe how you could test if this had happened with your experiment.

Conclusion

Describe the relationship between the distance the rubber bands are pulled back and the distance a marshmallow moves.

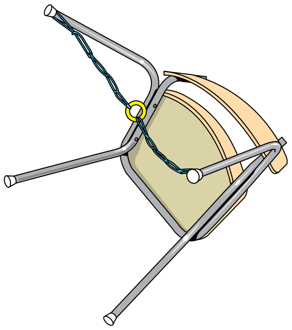


Figure 1 Secure the chain to the legs of a chair.

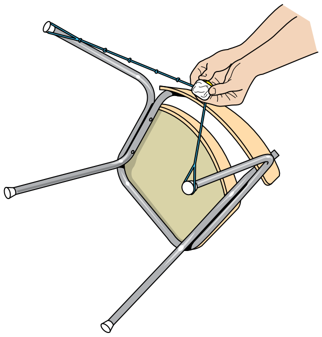


Figure 2 Pull back the marshmallow and measure the distance.

2.1 Identifying rocks

SKILLS LAB

Aim

To use a key to identify different types of rocks.

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 group's.

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

Figure 1 Rocks can be identified using a dichotomous key.

2.2 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.
5. Compare the results of your crystals to those grown by others in your class. Describe the largest and smallest crystals formed.
6. Identify any factors that could explain any variation in the crystals formed.

Conclusion

Describe what you learnt about the factors affecting crystal size.

Figure 1 Different factors can affect the size of a crystal.

2.3 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 2.4.
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 2.4.

Results

Include images of your rocks. Describe what your rocks look like using the terms in Topic 2.1 (page 24).

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

2.4 Making a metamorphic rock

EXPERIMENT

Aim

To make a sample of a metamorphic rock.

Materials

- 2 shale rock samples from Experiment 2.3
- 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 2.3 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

2.5 Modelling the rock cycle

SKILLS LAB

Aim

To model the rock cycle.

What you need:

Crayons (3 different colours), sharpener, 2 sheets of aluminium foil, 2 wooden blocks, beakers, 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.
7 Describe one way this rock model did not represent what occurs in the real world. This is referred to as the limitation of the model.

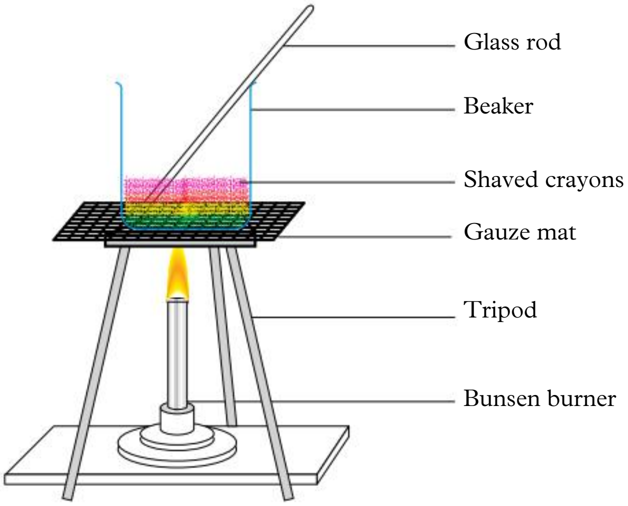


Figure 1 Experimental set-up

Figure 2 Colourful crayons

2.6 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 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. Determine 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.

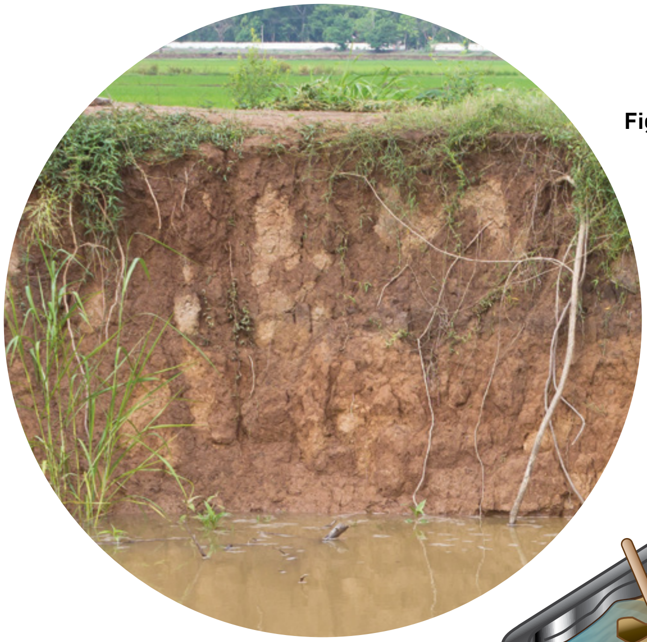


Figure 1 Soil erosion

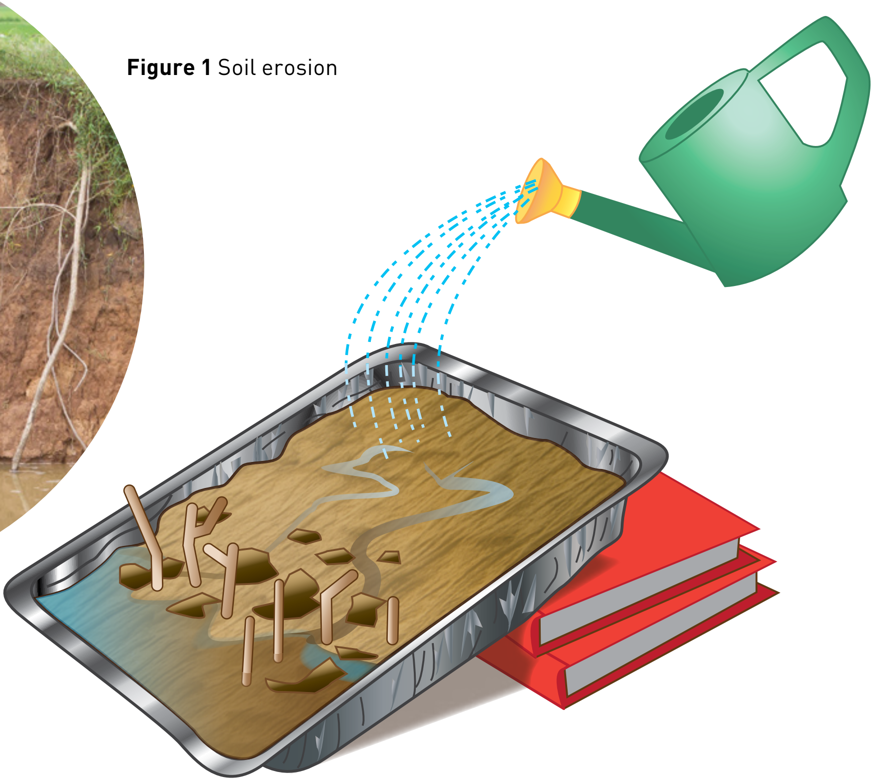


Figure 2 Experimental set-up

2.7 Making a fossil

EXPERIMENT

Aim

To make a trace fossil in sedimentary rock.

Materials

- Dry clay
- Dry sand
- Plaster of Paris
- Water
- Mortar and pestle
- Teaspoon
- 1 empty matchbox
- White tile
- Dry leaves, plastic toy animals etc

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 following dry ingredients for the sedimentary rock on a white tile.
   - ½ teaspoon of dry clay
   - 4 teaspoons of sand
   - ½ teaspoon of plaster of Paris
3. Pile up your ingredients into a little hill and make a small dip in the centre for the water.
4. Slowly add 2 teaspoons of water and stir until the ingredients are uniformly mixed. Be careful not to make the mixture too wet.
5. Press your mixture into the empty matchbox.
6. Gently place the dry leaf or toy animal into the surface of the mixture. Carefully remove the leaf or animal so that an imprint has been left in the surface.
7. Label the rock containing the trace fossil with your name and leave it to dry for 2 days.
8. When your 'rock' is dry, peel off the matchbox and examine your sample. Take digital photos of your trace fossil.

Results

Include images of your trace fossil. Describe what your fossil looks like.

Discussion

1. Describe how fossils are formed.
2. Describe what would happen if the rock containing your trace fossil was exposed to large amounts of pressure or a high temperature.

Conclusion

Describe the formation of a trace fossil.

Figure 1 This dinosaur footprint is an example of a trace fossil.

2.8A 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

2.8B What if a muffin were mined in different ways?

EXPERIMENT

Aim

To compare the effectiveness of different methods of mining and their impact on the environment.

Materials

- 2 homemade chocolate chip muffins (each with the same number of chocolate chips – approximately 20)
- Plastic plates
- Spoons

Method

1 Imagine each muffin is an area of land that contains a valuable ore: chocolate.

2 Use spoons to 'mine' the chocolate from the first muffin using the 'open cut' method, taking layers off the top and collecting the chocolate as it appears.

Inquiry: What if the muffin was mined using the underground method?

1 Describe how this muffin can be mined so that the top environment remains intact.

2 Identify the (dependent) variable that you will measure and/or observe to determine which method was more effective.

3 Identify two variables that you will need to control to ensure that the test is reproducible.

4 Write down the method that you will use to complete your investigation.

5 Draw an appropriate table to record your results.

6 Show your teacher your planning to obtain approval before starting your experiment.

Results

Draw or take a picture of your two muffins.

Discussion

1 Describe which method recovered the most chocolate ore.

2 Identify which method recovered the chocolate ore in the shortest time.

3 Identify which was the easiest method to recover the chocolate ore.

4 Explain which method would allow the environment to be quickly rehabilitated.

Figure 1 Equipment for 'muffin mining'

3.1A Cooling and layers

EXPERIMENT

Aim

To investigate whether cooling of a substance causes layers to form.

Materials

- 250 mL beaker
- Copper sulfate
- Spatula
- Glass stirring rod
- Bunsen burner
- Heatproof mat
- Tripod
- Gauze mat

Method

1 Set up the heating equipment and boil 50 mL of water in the beaker (Figure 1).

Figure 1 Heat the water.

2 When the water is boiling, turn off the gas. Add the copper sulfate to the boiled water a little at a time, using the spatula and stirring constantly to make it dissolve (Figure 2). Stop when no more copper sulfate will dissolve.

Figure 2 Add copper sulfate.

3 Allow the beaker of saturated copper sulfate solution to cool undisturbed for about 20 minutes, then carefully place it in the fridge. Examine it after an hour if possible (or the next day).

4 When the beaker has cooled, without moving the beaker, examine its contents and observe where any solid copper sulfate might be located.

Figure 3 Examine the cooled contents.

Results

Describe what happened as the beaker cooled, and record where any solid copper sulfate is located.

Discussion

1 Contrast (the differences between) the density of solid copper sulfate and liquid water.

2 Compare (the similarities and differences between) the formation of solid copper sulfate from a solution, to the formation of solid tectonic plates formed from a molten mass.

Conclusion

Explain why layers are formed when a substance cools.

3.1B Modelling the parts of the Earth

CHALLENGE

⚠ **CAUTION!** Some students might have an egg allergy.

Aim

To model the layers of the Earth.

What you need:

Hard-boiled egg, teaspoon

What to do:

1. Gently crack the shell of the hard-boiled egg. The egg can be seen as a tiny model of the Earth. The thin shell can represent the Earth's crust, and within the shell can represent the Earth's mantle.
2. Move the pieces of the shell around. These pieces can represent the Earth's tectonic plates. Notice how the pieces of shell collide in some places and reveal pieces of the 'mantle' in others. This also happens on the Earth, resulting in volcanoes, earthquakes and the formation of mountain ranges.
3. Break the egg completely open. The yolk represents the core of the Earth.

Discussion

1. In your model, the shell represents the Earth's crust. Describe what happened when you pushed two pieces of shell towards each other.
2. Describe an example of how this can happen with the Earth's crust.
3. Identify which parts of the egg should be liquid in a more accurate model of the Earth.

Figure 1 The egg's shell represents the Earth's crust, and within represents the mantle and the core.

3.2A Reconstructing Pangaea

CHALLENGE

Aim

To model how the Earth's continents have moved over time.

What you need:

Photocopy of a map of the world, scissors, glue

What to do:

1 Roughly cut out the continents of the world and fit them back together in the shape of Pangaea.
2 Remember to cut off India from Asia, because it was once separated.
3 When you are happy with your supercontinent, glue the pieces into your science book.
4 You may like to add to your supercontinent what you know about the locations of the fossil and glacier evidence.

Discussion

1 Explain why fossil twigs, roots and pollen found in Antarctica are almost identical to those found in Tasmania.
2 Identify one other country that may have fossils similar to those found in Australia.
3 Explain how this activity provides evidence of tectonic plate movement.
4 Explain one factor that scientists would need to consider before they collected rocks from Antarctica.

Figure 1 Fossil ferns in a rock

3.2B Milo convection currents

CHALLENGE

This is a whole-class demonstration.

Aim

To model the convection currents that move tectonic plates.

What you need:

1 small container of Milo® (Nesquik® will dissolve too easily), 1 litre of milk, saucepan, hotplate

CAUTION! Do not eat in the laboratory. If the Milo will be consumed, this experiment should be done at home or in a canteen/cafe.

Figure 1 The surface Milo will move sideways as hotter milk rises from the bottom of the container.

What to do:

1 Pour the milk into the saucepan and add a very thick layer of Milo over the surface.

2 Place the saucepan on the hotplate and heat slowly without stirring.

3 Record your observations of how the Milo cracks and moves as a result of the hot milk rising to the surface.

Discussion

1 Describe how the heat from the hotplate moved into the milk. Identify which part of the milk was first heated.

2 Explain why heated milk rose to the surface.

3 Explain why the Milo moved the way it did when the heated milk rose to the surface.

4 Compare the movement of milk and Milo in this experiment to the breaking up of Pangaea into smaller pieces.

3.3 Modelling plates

CHALLENGE

Aim

To model the different boundaries between tectonic plates.

What you need:

Play dough, spatula

What to do:

1 Wash your hands before starting this activity.
2 Use a clean spatula to cut the play dough in half lengthways and place the two halves beside each other.
3 To illustrate a transforming boundary, gently push the 'plates' so that their sides are in firm contact with each other, then slide one half of the play dough forwards and the other backwards. Record your observations.
4 To illustrate the force of compression associated with mountain building when continental plates collide, push on both sides of the play dough to squeeze it together. Record your observations.

Discussion

1 Describe the vertical movement of the top of the play dough when you modelled a transforming boundary.
2 Describe what happened to the top of the play dough when you modelled a converging boundary.
3 Describe how you would model a diverging boundary.
4 Predict how the play dough would change in your model of a diverging boundary.
5 Test your prediction. Compare your observations to your prediction.

Figure 1 Play dough can be used to model plate boundaries.

3.4A Volcanic bubbles

CHALLENGE

Aim

To model the formation of gas during a volcanic reaction.

What you need:

Powdered chalk, vinegar, red food dye, bottle of lemonade

What to do:

1 Mix a small amount of powdered chalk with one teaspoon of vinegar and a few drops of food dye. The reaction produces carbon dioxide bubbles and the food dye makes the froth look like lava.

2 Tiny gas bubbles form as the pressure in a bottle of lemonade is released. As the pressure is released more, bigger bubbles form. This can be seen by slightly twisting the screw top of a bottle of soft drink, such as lemonade. The more you twist the lid, and the more pressure that is released, the bigger the bubbles. This is like the cooling of magma inside a volcano.

Discussion

1 Compare (the similarities and differences between) the formation of carbon dioxide in Step 1 with the gases formed in lava.

2 Compare the pressure in the lemonade bottle to the pressure in a volcano.

3 Step 1 described the formation of gases, while step 2 described how the size of the bubbles increased as pressure was released. Use this information to describe the formation of pumice (Figure 1) during a volcanic eruption.

Figure 1 Gas bubbles formed the holes in this piece of pumice rock.

3.4B Modelling a tectonic boundary

CHALLENGE

Scientists can use a variety of equipment to measure the location (latitude and longitude) and strength of an earthquake. The amount of damage that can be done by an earthquake is dependent on the magnitude and the depth of the plate movement.

Aim

To recreate a 2D model of a tectonic boundary.

What you need:

Map of South America, computer, Excel software

What to do:

Part A

1 Make a copy of the map of South America.

2 Map the location of each earthquake (the latitude and longitude) identified in Table 1.

Part B

1 Open an Excel spreadsheet on your computer.

2 Enter the Longitude and Depth (km) into the spreadsheet.

3 Highlight the two columns on the table.

4 Select the 'Insert' tab, and 'Scatter graph'.

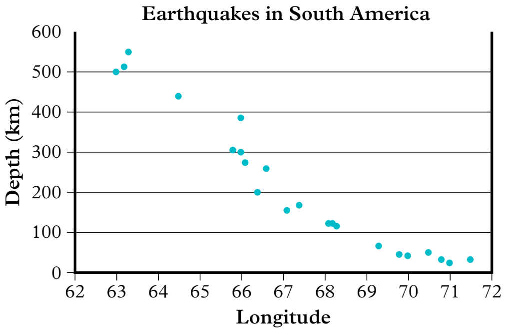


Figure 1 A scatter graph showing the longitude and depth (km) of earthquakes in South America.

Discussion

1 Describe the location of the earthquakes on the South American continent.

2 Explain the location of the earthquakes on the South American coast.

3 Describe the relationship between the longitude of the earthquakes and the depth of the earthquake.

4 Describe what is happening to the two tectonic plates at that boundary.

Table 1 Earthquake data from South America

Station	Latitude	Longitude	Depth (km)	Magnitude
1	19.8	66.6	259	4.6
2	27.8	63.2	513	5.1
3	26.2	63.3	550	4.8
4	31.2	71.5	33	5
5	23.2	66.4	200	4.8
6	23.5	71	25	5
7	24.5	70.8	33	5
8	21.3	68.2	122	4.7
9	23.6	70	42	5
10	23.5	70.5	50	
11	22.9	68.3	115	4.8
12	34.1	69.8	45	
13	22.3	66.1	274	5
14	23.2	69.3	67	4.9
15	22.5	67.4	168	4.5
16	19.5	65.8	305	4.5
17	21.4	68.1	123	5.1
18	27	63	500	4.9
19	27.2	67.1	155	4.7
20	20.4	66	300	4.5
21	25.6	66	385	5
22	22.2	64.5	440	4.8

3.5 Design an earthquake-proof house

CHALLENGE

Design brief

Design and build a house that will be stable in an earthquake zone. Test your design by placing the house in a large clear-sided tub of sand and water.

Criteria restrictions

- The house can be built from the materials provided (These might include pipe cleaners, icy pole sticks, sticky tape, paper, aluminium foil, cardboard, plasticine, play dough, wire.)
- The house must be closed in with walls and a roof.
- The house must have foundations that go into the soil.

Questioning and predicting

- Identify the materials that you will use.
- Identify the properties of the materials that you will use.
- Use your knowledge of earth movement to explain why your house will survive an earthquake.

Planning and conducting

- ¾ fill the tub with fine sand. Pour water into the container until it is just below the surface. Make sure that it does not rise above the surface of the sand. Place a small brick on the surface of the sand. Slide the tub rapidly back and forth until water rises to the surface and the brick starts to sink. This is an example of liquefaction. Use your hands to mix up the sand and water again.
- Explain how you will measure the effectiveness of your house design.
- Describe of the type of earth movement and the length of time of the earthquake.

Processing, analysing and evaluating

1 Describe the movement of your designed house during the model earthquake.

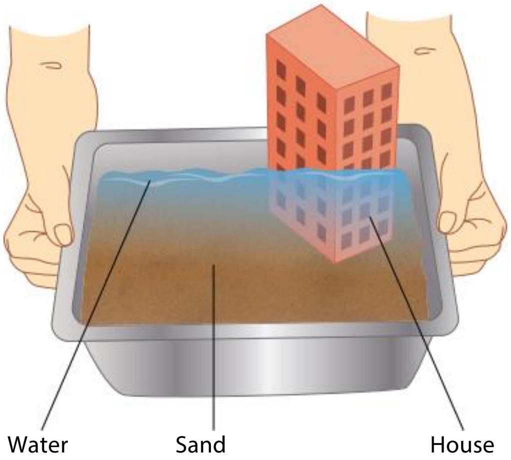


Figure 1 General set-up of experiment

2 Compare the effectiveness of your design against other houses designed by your peers.

3 Describe the limitations of your design (the earth movements that will cause it to collapse).

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 report.

4.1 Draw flow diagrams of energy transfer

SKILLS LAB

Aim

To identify the transfer of energy between objects.

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.

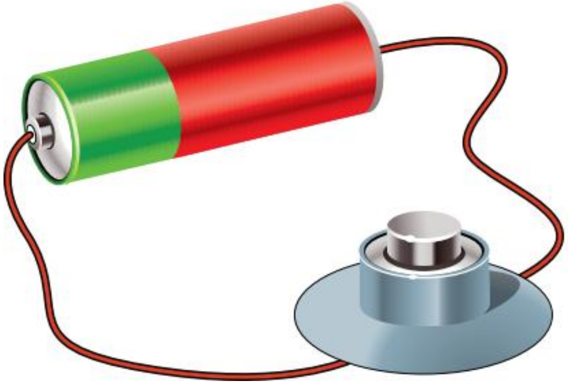


Figure 2 Station 2 Use wires to connect the buzzer to the battery.

Station 3

1 Gently tap the forked end of the tuning fork on a 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.

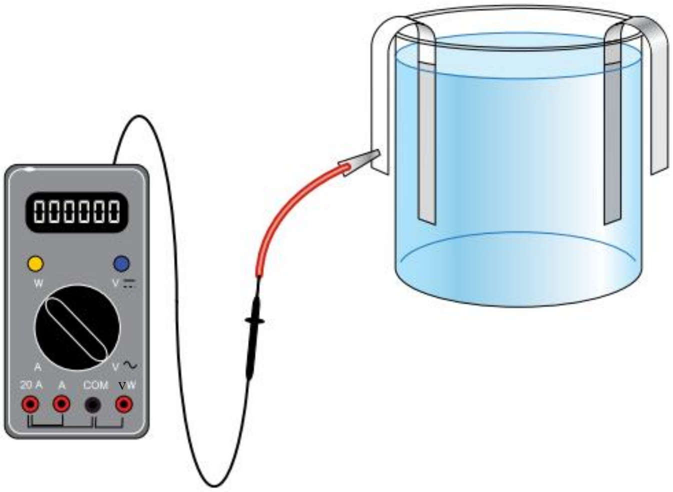


Figure 4 Station 4 Connect the saltwater battery to a multimeter.

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 A plastic windmill

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 you could increase this output energy.

Figure 7 Tape measure

Figure 8 At a standstill

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.

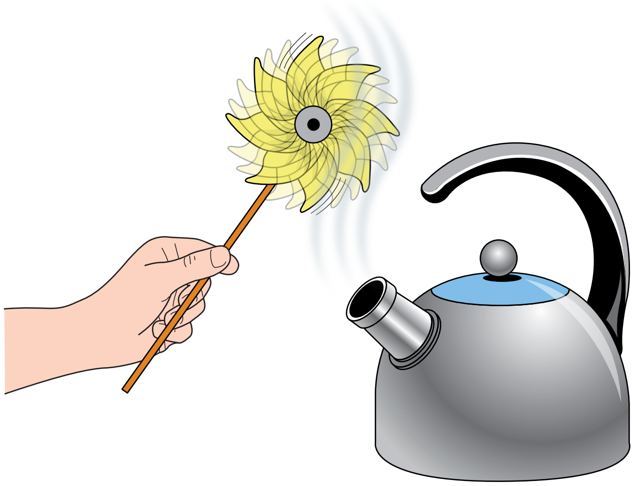


Figure 6 Station 5 A toy windmill acts like an electricity-generating turbine.

Figure 9 Station 6 What path does the energy take as the car moves down the ramp?

4.2 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?

1. Write a prediction or hypothesis for your inquiry.
2. Identify the (independent) variable that you will change from the first method.
3. Identify the (dependent) variable that you will measure and/or observe.
4. Identify two variables that you will need to control to ensure a fair test. Describe how you will control these variables.
5. Write down the method you will use to complete your investigation in your logbook.
6. Draw a table to record your results.
7. Show your teacher your planning for approval before starting your experiment.

Results

1. Complete Table 1.
2. 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.

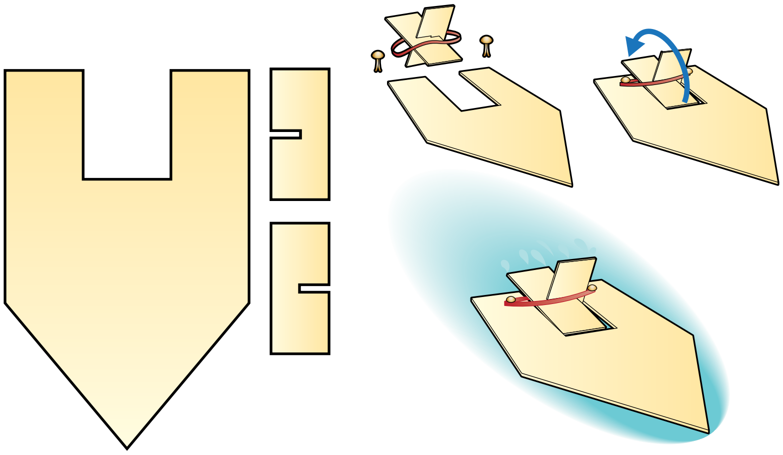


Figure 1 The parts and method of assembly for a rubber band boat

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				

4.3 Exploring sound energy

CHALLENGE

Aim

To determine how sound energy is generated and transferred.

What you need:

Tuning fork, wooden table (alternatively, a 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?

4.4 Energy converters

CHALLENGE

Aim

To identify energy transformations.

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

4.5 Making a simple torch circuit

CHALLENGE

Aim

To use a simple circuit to transform electrical energy to light energy.

What you need:

Pieces of insulated electrical wire with the ends stripped bare, 1.5 V battery, 1.2 V torch globe, hand lens

What to do:

1 Try different arrangements of the wires, battery and torch globe to make the globe light up. Draw each arrangement that you tried.

2 Use circuit diagrams to record some of the arrangements that work and some that do not.

3 Use the hand lens to look carefully at the filament in the globe. The filament is the tiny wire inside the glass of the globe – the part that glows brightly when the globe lights up. Draw what you see.

4 Use the hand lens to look at how a globe holder (the base of a globe) is constructed.

Discussion

1 Select one of the arrangements that did not allow the globe to light up. Explain why this arrangement did not allow electricity to pass through the circuit.

2 Describe how the filament in the light globe is able to transform electricity into light and heat.

3 Describe how the globe holder connects the light globe to the circuit.

4 Some battery manufacturers claim that their brands of batteries last longer than other batteries. Design an experiment that you could use to test this claim.

Figure 1 How does a torch work?

4.6A 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.

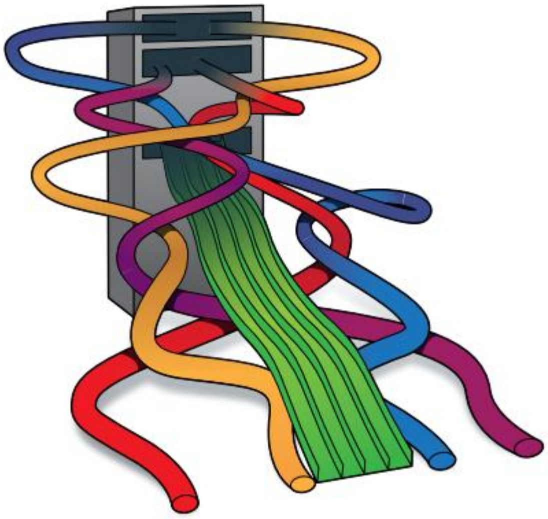


Figure 1 Waterslides convert gravitational potential energy to kinetic energy.

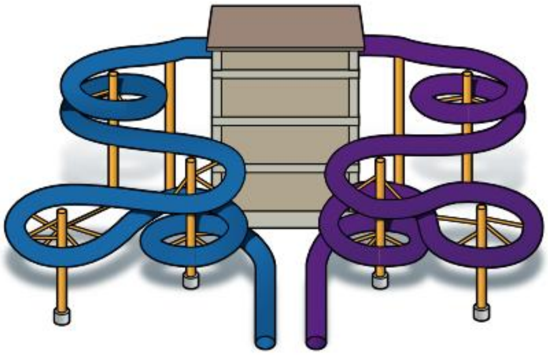


Figure 2 Long waterslides have more friction than short waterslides.

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 and the energy transfers and transformations 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.

4.6B 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 stick 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

Complete your results table.

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

The Sun's energy

Aim

To transform light energy to movement energy.

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.

Table 1 Record of propeller rotations

Date	Time	Revolutions of propeller/minute	Weather conditions

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.

5.1 Classifying atoms according to their properties

CHALLENGE

Aim

To make a set of atomic cards.

What you need:

Cardboard, felt-tipped pens, scissors

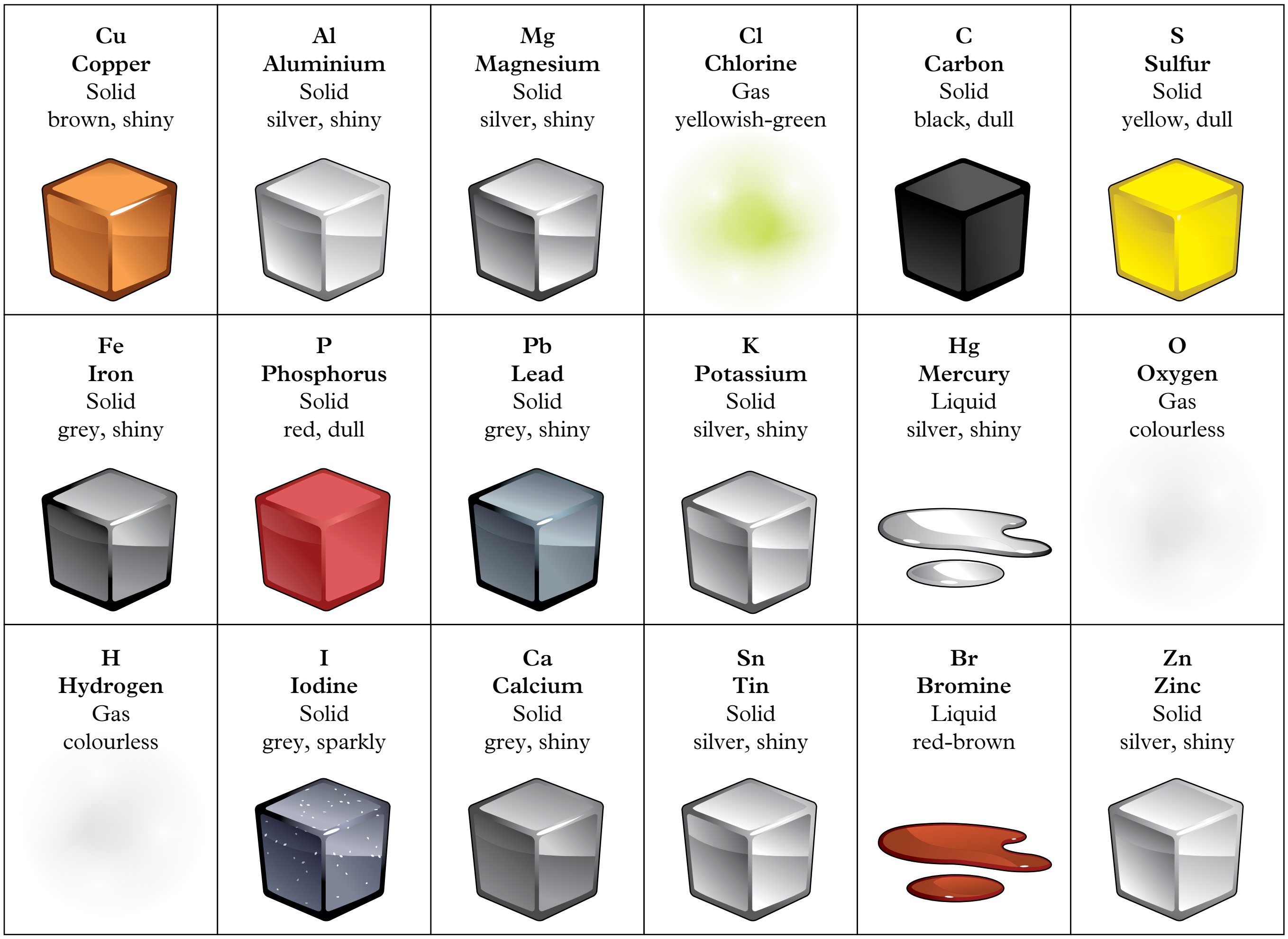
What to do:

1 Make up some cards like the ones shown in Figure 1 to represent the different atoms.

2 Sort the cards into those with a one-letter symbol and those with a two-letter symbol.
   - Identify the number of atoms that have a one-letter symbol.
   - Identify the number of atoms that have a two-letter symbol.
   - Explain why classifying atoms according to their symbol is a bad idea.

3 Sort the cards according to the colour of the atom.
   - Identify the number of atoms that are silver.
   - Identify the number of atoms that have another colour.
   - Explain why classifying atoms 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 atoms that are solids, liquids or gases.
   - Explain why classifying atoms 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 atomic cards

5.2A Identifying the elements in the periodic table

CHALLENGE

Aim

To identify the different properties of elements in the periodic table.

What you need:

An unshaded copy of the periodic table, coloured pencils

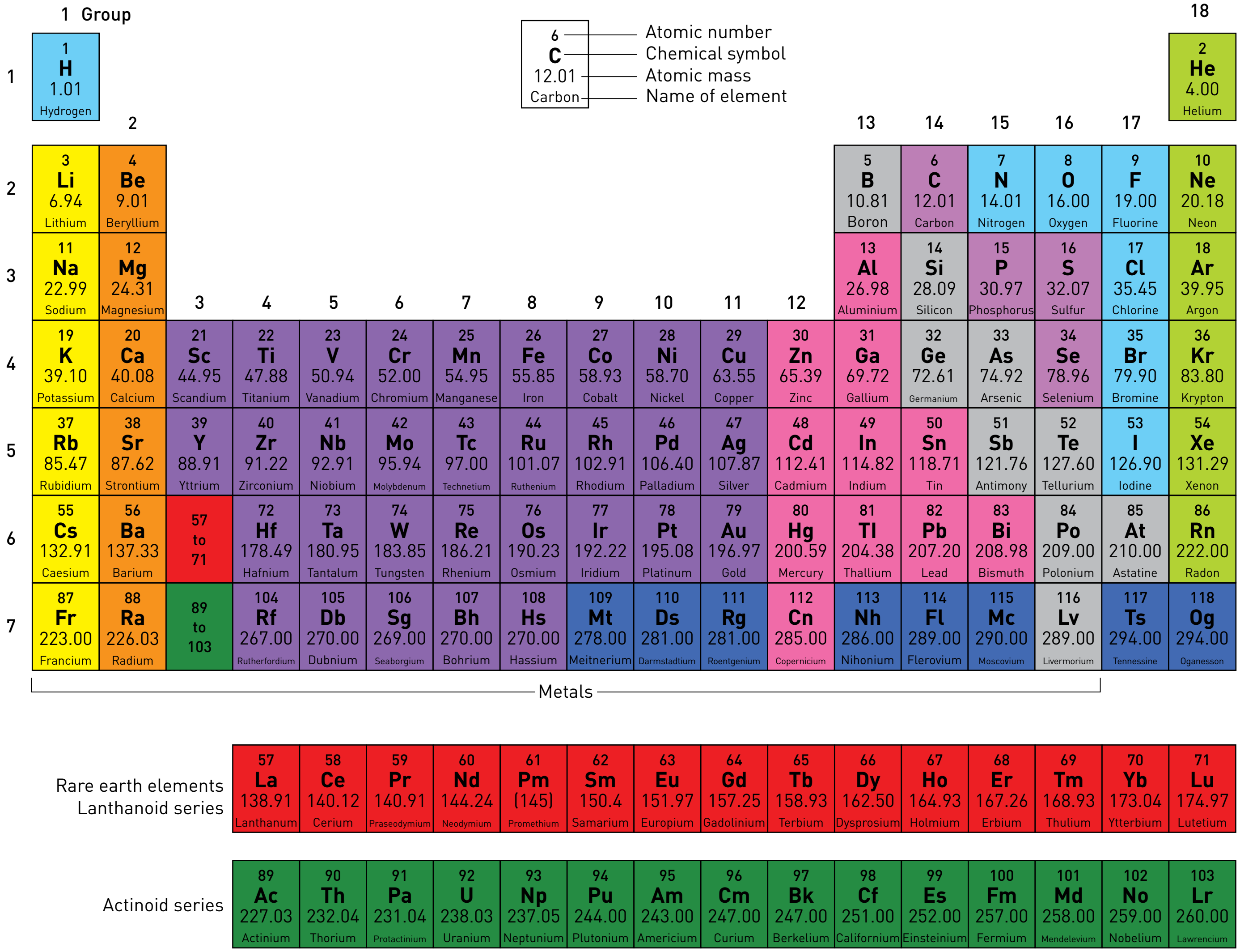
What to do:

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.



	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 **Tl** 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 1 The periodic table

5.2B Properties of the elements

EXPERIMENT

Aim

To observe the differences between different elements of the periodic table.

Materials

- Steel wool
- Forceps
- Battery
- 3 wires
- Lamp
- 0.5 M hydrochloric acid
- Deionised/distilled water
- 6 test tubes
- Test-tube holder

Samples for testing

- Aluminium metal strips
- Copper metal strips
- Magnesium metal strips
- Graphite/lead pencil
- Zinc metal strips
- Iron nail (non-galvanised)

Method

1. Use the steel wool to rub a small section of your first sample. Record the colour and appearance (dull or shiny) in Table 1.
2. Use the forceps to try to bend your sample. Identify whether it is malleable (able to bend) or brittle (breaks when bent). Record this in Table 1.
3. Set up a circuit with the battery, lamp and wires as shown in Figure 1. Connect the two loose wires to your sample. 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.

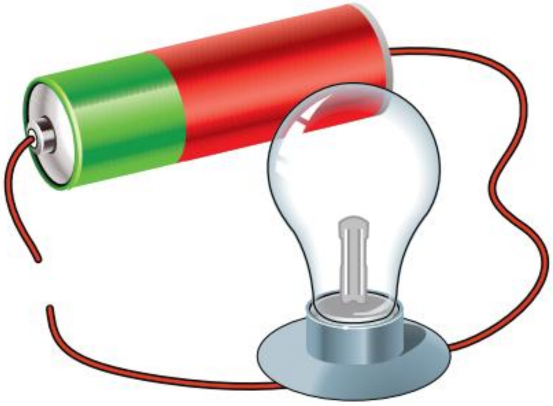


Figure 1 This incomplete circuit can measure the conductivity of objects.

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 (sample)	Is it shiny/ dull?	Is it malleable/ brittle?	Does it conduct electricity?	Does it react with acid?

Figure 2 Steel wool

5.3 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 up the Bunsen burner 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)

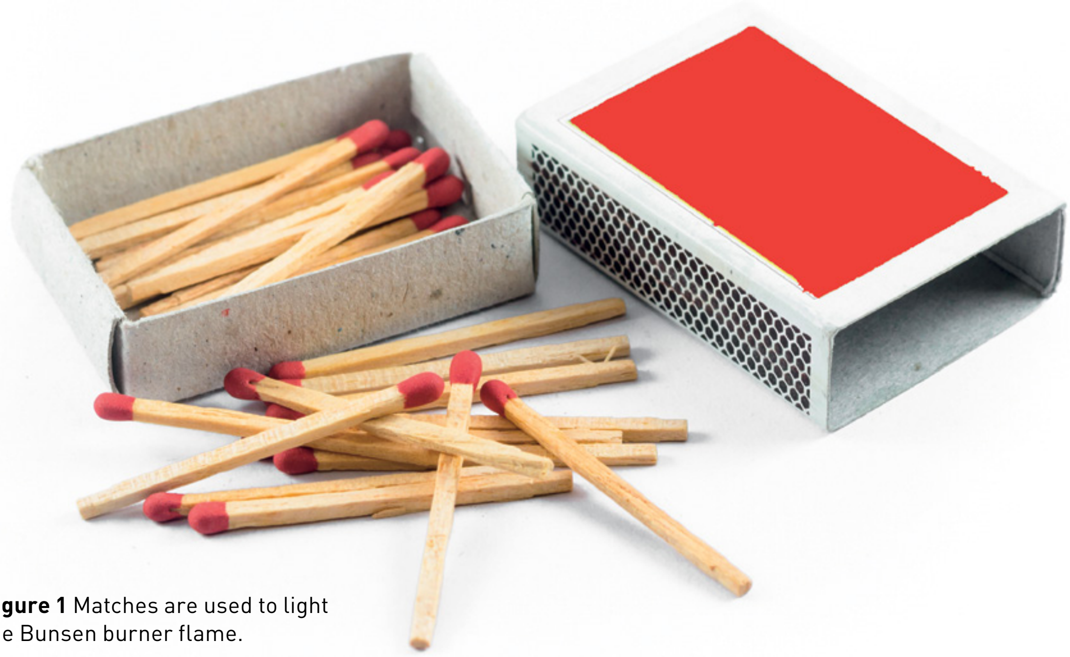


Figure 1 Matches are used to light the Bunsen burner flame.

5.4 Modelling elements, molecules and compounds

CHALLENGE

Aim

To model different elements, molecules and compounds.

What you need:

Atomic modelling kit OR different coloured play dough rolled into small balls (black, white, red, blue), toothpicks, newspaper

What to do:

1 Use your equipment to model each of the following molecules or mixtures.

2 Copy Table 1 into your notebook and complete. Include labelled drawings.

Questions

1 Describe the difference between a molecule and a mixture.

2 Explain why mixtures are presented by percentages and molecules are represented by formulas.

Table 1 Modelling results

Substance	Molecule or mixture?	Atoms present	Drawing of model
H_2O			
CO_2			
CH_4			
N_2			
Soda water (CO_2 in H_2O)			
Air containing O_2, CO_2, N_2, H_2			

Figure 1 Use toothpicks to help hold your model atoms together.

5.5A 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.

5.5B Exploring physical changes

CHALLENGE

Aim

To identify the physical changes in materials.

What you need:

Aluminium drink can, 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

5.6A Making caramel

CHALLENGE

Aim

To identify the chemical change when heating sugar.

What you need:

Sugar, test tube, test-tube holder, Bunsen burner, 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 Sugar undergoes a chemical change when heated.

5.6B 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)
- 30 mL of 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 30 mL of 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.
7 Plan an experiment to test the science question, 'What if twice as much magnesium was used in Part C of the experiment?'

Conclusion

Explain what you observed about the reactants and products of chemical reactions.

5.7 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				

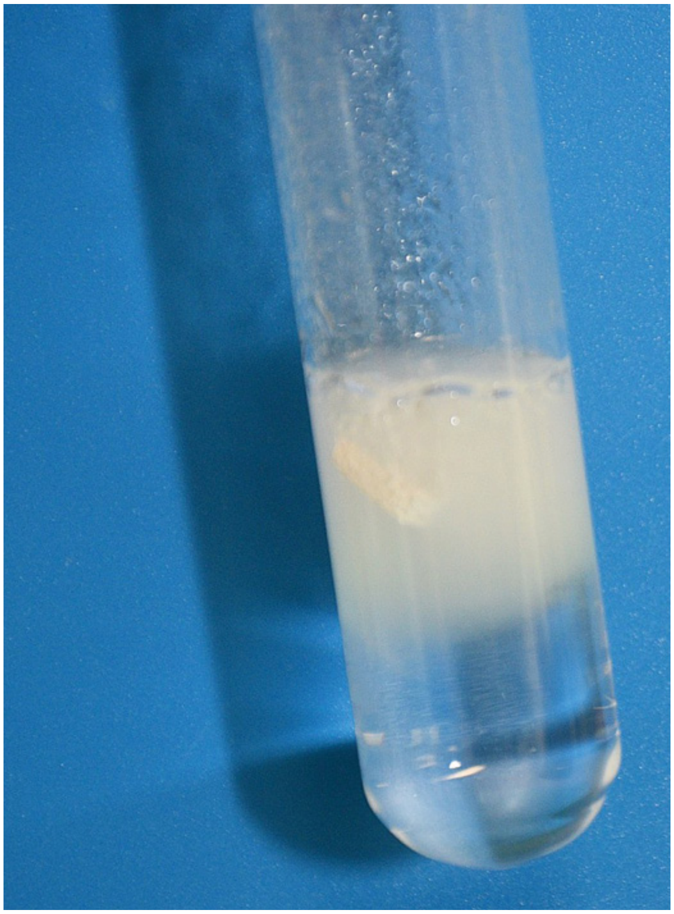


Figure 1 Magnesium ribbon reacting with hydrochloric acid

5.8A 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 whether 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.

5.8B Speeding up reactions with enzymes

EXPERIMENT

Aim

To investigate the effect of enzymes on breaking down hydrogen peroxide.

Materials

- 1 packet of dried yeast
- 2 × 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 Fill one beaker with 10 mL of hydrogen peroxide.
2 Light a splint and then blow it out. Place the glowing splint in the top half of the beaker.
3 Record your observations.
4 Add the yeast to the second beaker.
5 Add 10 mL of the hydrogen peroxide into the beaker containing the yeast.
6 Repeat steps 2–3 for the second beaker.

Results

Record your observations in a table.

Discussion

1 Describe whether the breakdown of hydrogen peroxide into oxygen and water was noticeable.
2 Describe what happened to the rate of hydrogen peroxide breakdown when the yeast was present.
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

5.9 Making casein glue

EXPERIMENT

Casein is a protein in milk. It can be extracted from milk and chemically changed so it has the properties of a glue. It is also considered biodegradable.

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.
4. Describe why some people may prefer to use a biodegradable glue.
5. Describe how a biodegradable glue could be used in sustainable packaging.

Conclusion

Describe what you know about making glue.

Figure 1 Casein from milk can be used to make glue.

6.1 Drawing cells

SKILLS LAB

Aim

To identify the different structures of onion cells.

What you need:

Microscopes, prepared slides, pencil and paper for drawing, 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.

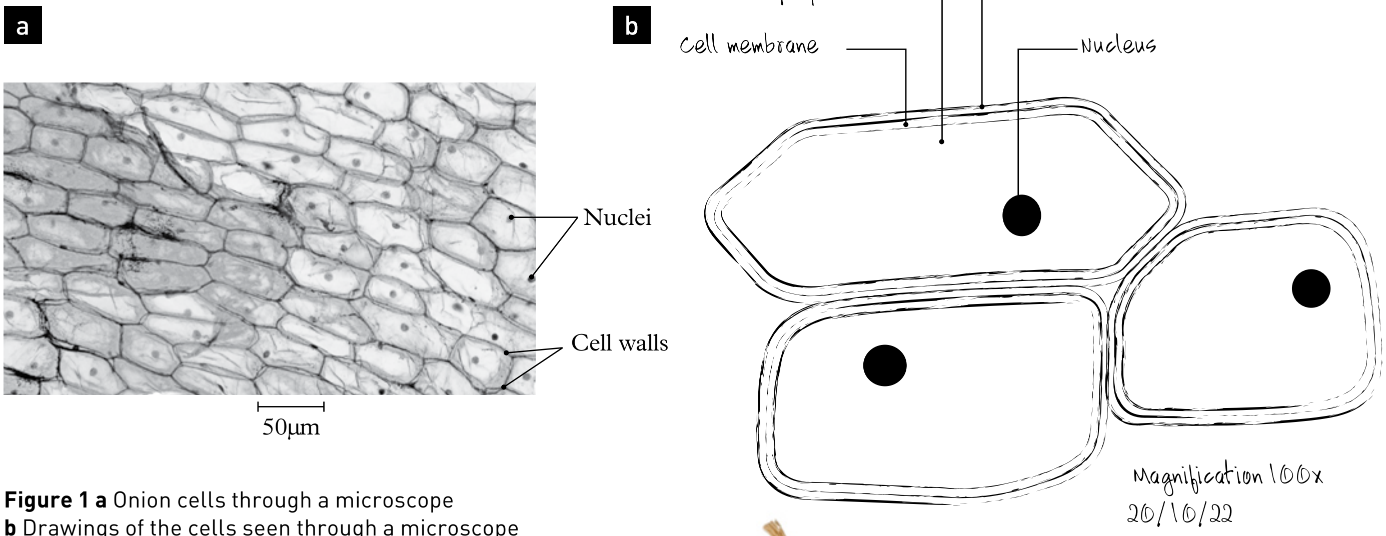


Figure 1 a Onion cells through a microscope
b Drawings of the cells seen through a microscope

Figure 2 Keeping cells under wrap

6.2 Getting to know your microscope

Aim

To develop the skill of using a microscope.

CAUTION! Always use two hands to carry a microscope – one hand should be around the main part of the instrument and the other underneath it.

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 piece of sticky tape (transparent)

Figure 1 Use scissors to cut out words from the newspaper.

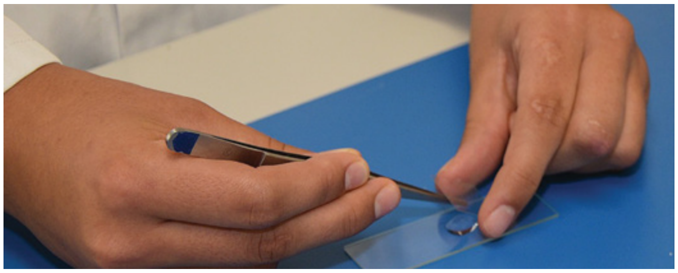


Figure 2 Gently lower the glass coverslip down until it is flat.

What to do:

1 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.

2 Place the slide on the stage, then select the objective lens with the lowest magnification first.

3 Cut out two small words from a piece of newspaper (Figure 1).

4 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 (Figure 2). This is called a wet mount.

5 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.

6 Use the coarse focus knob to bring the specimen into view (Figure 3). Find one letter from the newsprint to focus on.

7 Move the slide slightly towards your body and observe what happens.

8 Move the slide slightly to the left and observe what happens.

9 Increase the magnification by rotating the objective lens to a higher magnification.

10 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.

11 Calculate the total magnification.

12 Write the magnification next to your sketch.

13 Label and date the sketch.

14 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.

15 Sketch what you see.

16 Repeat with a piece of sticky tape and then a hair from your head.

Figure 3 Carefully adjust the focus of the microscope.

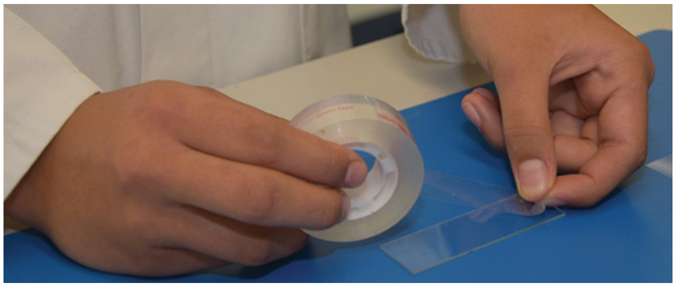


Figure 4 Repeat with a piece of sticky tape.

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

Aim

To compare the size of different cells and organelles.

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.

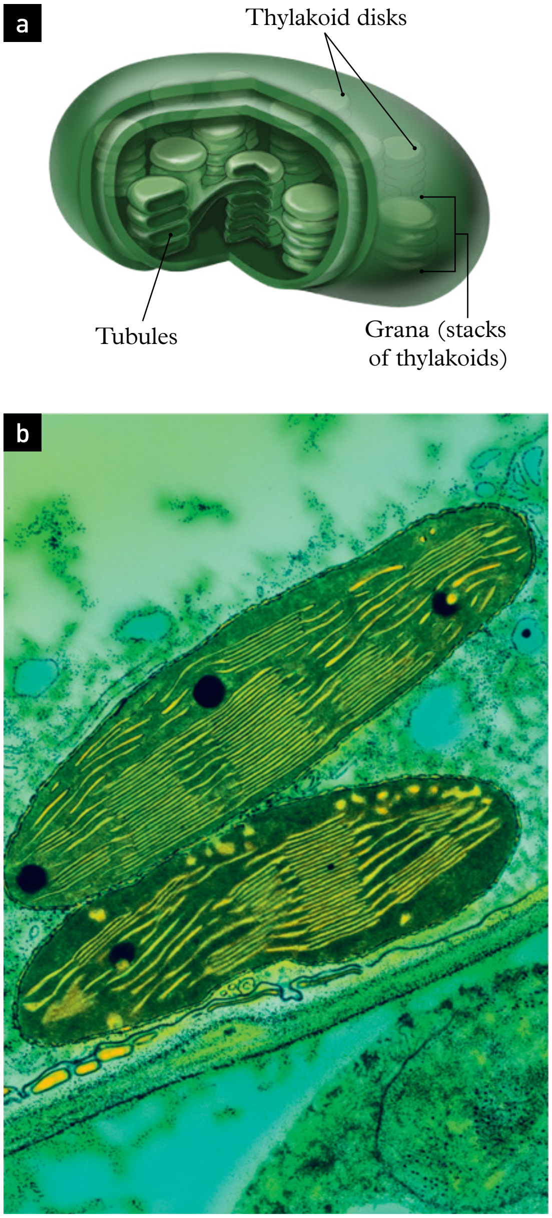


Figure 1 a Schematic diagram showing the structure of a chloroplast **b** Electron micrograph of chloroplasts

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 through the microscope. Try to identify the nucleus, which contains the DNA, and the cell membrane, cell wall 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 through the microscope.

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 through the microscope. Try to identify the cell membrane, cell wall and cytoplasm.

Figure 1 Adding iodine to the slide

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 6.3B)
- 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

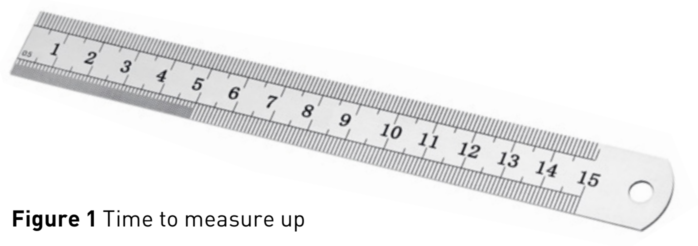


Figure 1 Time to measure up

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

Aim

To use the features of different cells to classify them into Kingdoms.

What you need:

Light microscope, four pre-prepared cells labelled A–D, supplied by your teacher (these may include leaf epidermal cells, yeast cells, protist 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.

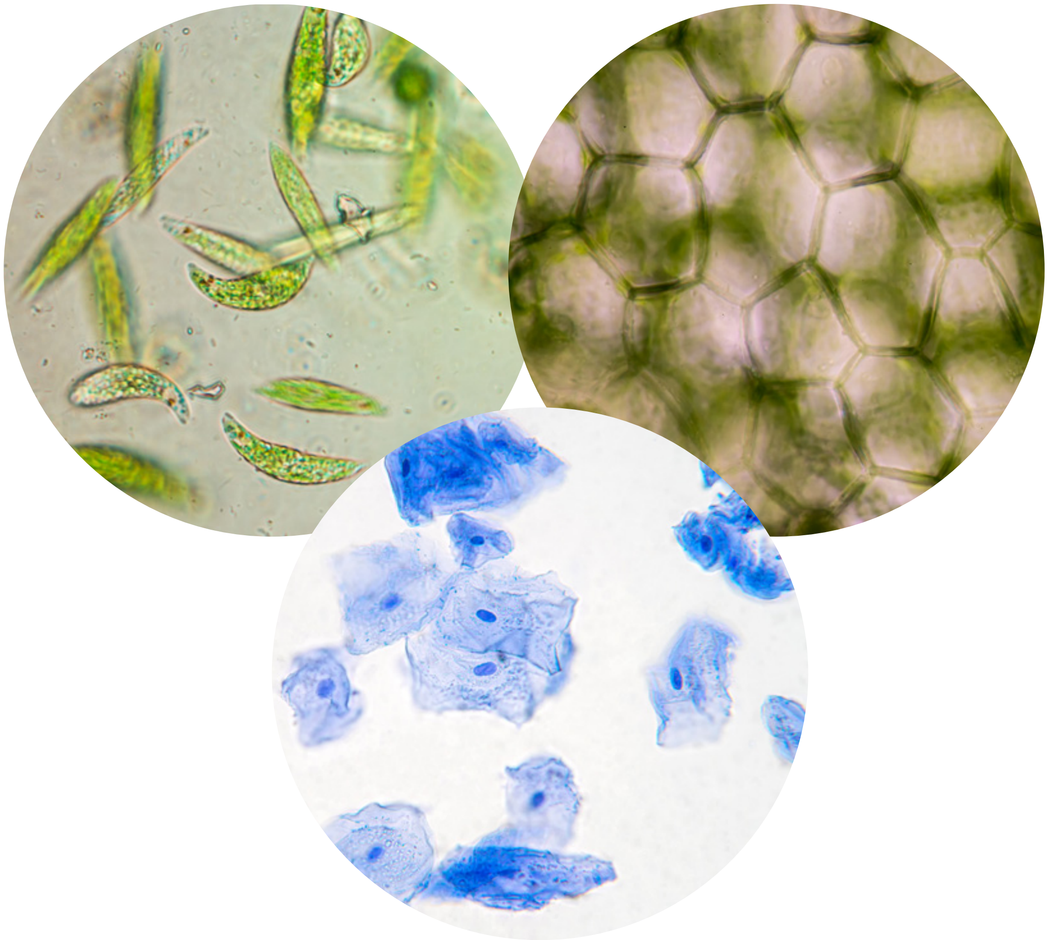


Figure 1 Use the features of the cells you observe to classify them into Kingdoms.

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.

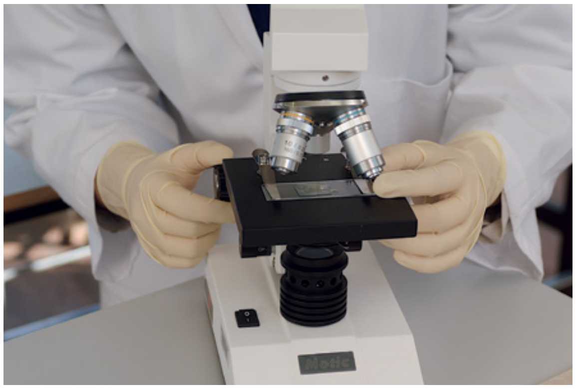


Figure 4 Focusing the microscope

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 128. 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.

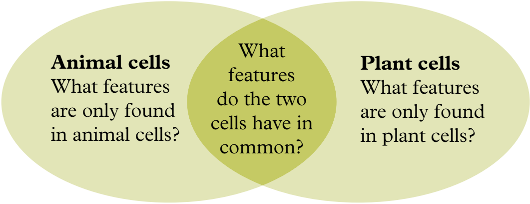


Figure 5 A Venn diagram can be used to show the similarities and differences between animal and plant cells.

Conclusion

Describe what you know about plant and animal cells.

6.5 Microbes all around

EXPERIMENT

CAUTION! Do not open the agar plate after incubation.

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 (Figure 1). 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.

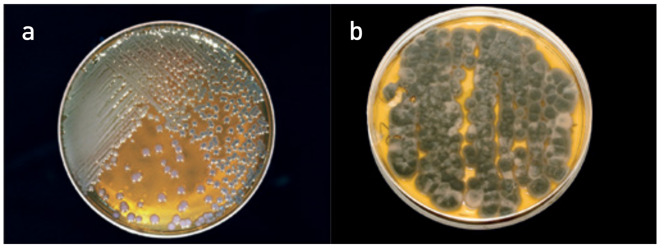


Figure 2 a Bacterial colonies growing on an agar plate
b Fungi tend to have a dusty or fuzzy appearance.

7.1A Dissecting a chicken wing

SKILLS LAB

Aim

To practice the skill of dissection.

What you need:

Chicken wing, newspaper, dissection board, forceps, probe, scalpel, dissection scissors, plastic bag for disposal

What to do:

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.

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

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

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

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

5 Use probes to look inside any folds.

6 Use forceps to hold and pull tissue.

7 Use a scalpel 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.

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.

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

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.

7.1B Brown paper body brainstorm

CHALLENGE

Aim

To identify the locations of different organs in the body.

What you need:

Roll or 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 141. 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 the 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 size.
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

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

Record your observations in your results table.

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.

Aim

To measure the capacity of a person's lungs.

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.

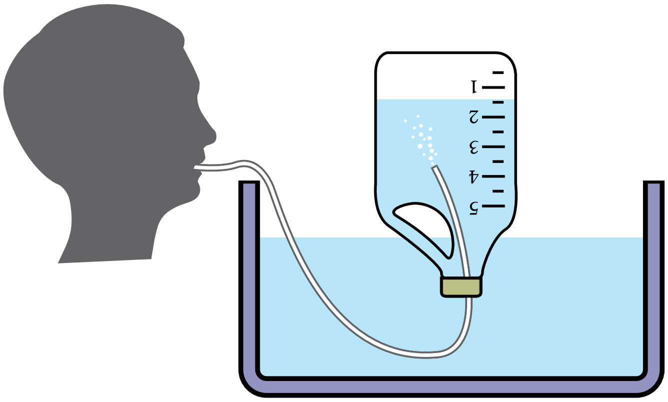


Figure 1 Experimental set-up

7.5B Fish dissection

CHALLENGE

Aim

To identify the respiratory organs in a fish.

CAUTION! Refer to Skills lab 7.1A for dissection skills and safety guidelines.

What you need:

A fish (complete with internal organs) from a fishmonger or market, dissection tools, newspaper, dissection board

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 its 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 (for example, a 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 Removing the gills

7.7 Heart dissection

EXPERIMENT

CAUTION! Refer to Skills lab 7.1A 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 the thickness 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.

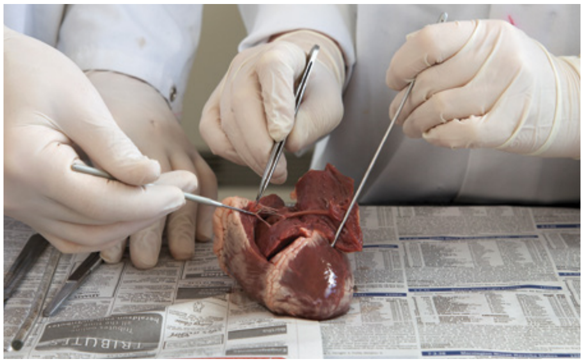


Figure 2 Compare the thicknesses of the right and left ventricles.

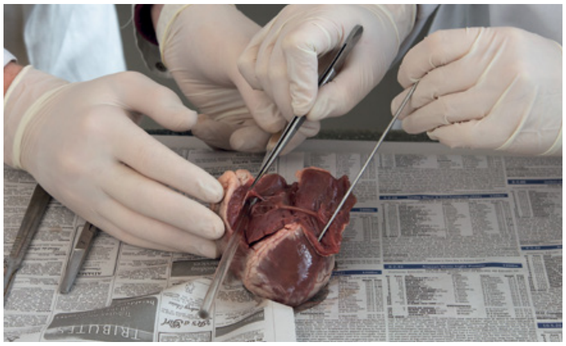


Figure 3 Use the dissecting probe to identify the arteries.

Figure 4 Identify the artery leaving the left ventricle.

7.8 Modelling blood flow

CHALLENGE

Aim

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 in 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 amount and evenness of water flow out of the narrow 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.

Figure 1 Representation of the circulatory system

7.9 Kidney dissection

EXPERIMENT

CAUTION! Refer to Skills lab 7.1A 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.

Figure 1 Sheep kidney cut in half longitudinally

7.11A Locating the stomata of a leaf

CHALLENGE

Aim

To identify the air exchange system of a plant.

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

7.11B Locating the xylem and phloem in a stem

CHALLENGE

Aim

To identify parts of the circulatory system of a plant.

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 transverse (horizontal) 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.

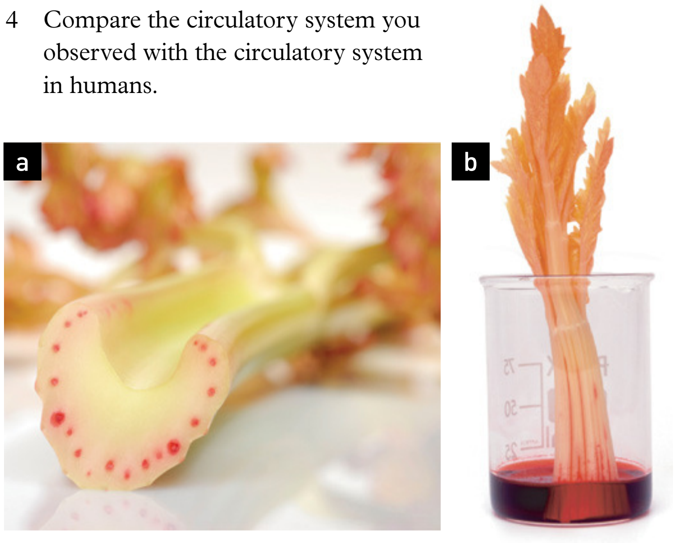


Figure 1 a The dye marks the path the water takes from the roots. **b** As water evaporates from the leaves, the coloured water replaces it.

7.11C Modelling root cells

CHALLENGE

Aim

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 plant root.

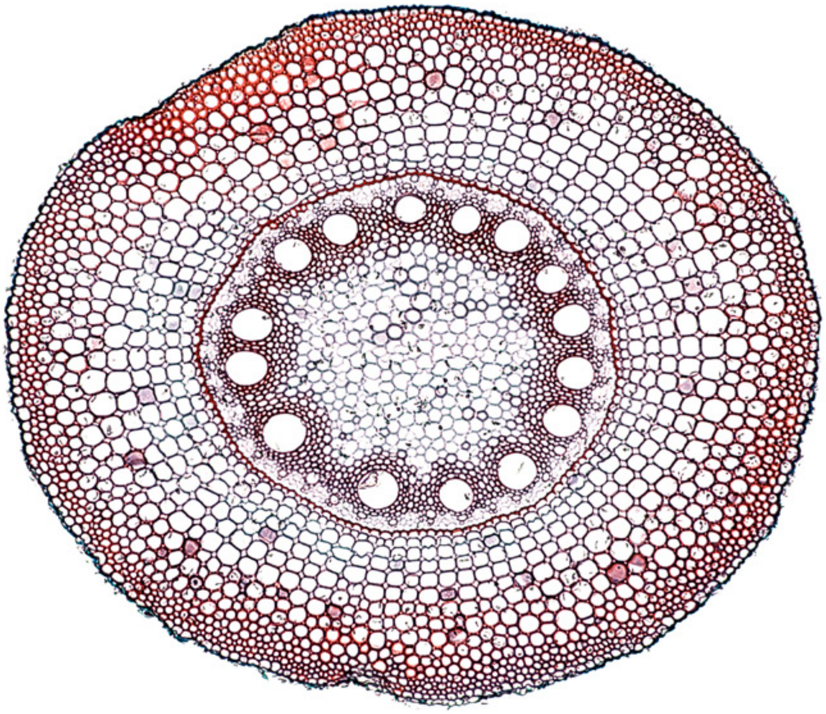


Figure 1 Cross section of a plant root under the microscope, showing cells in the root

7.11D 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 your 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.

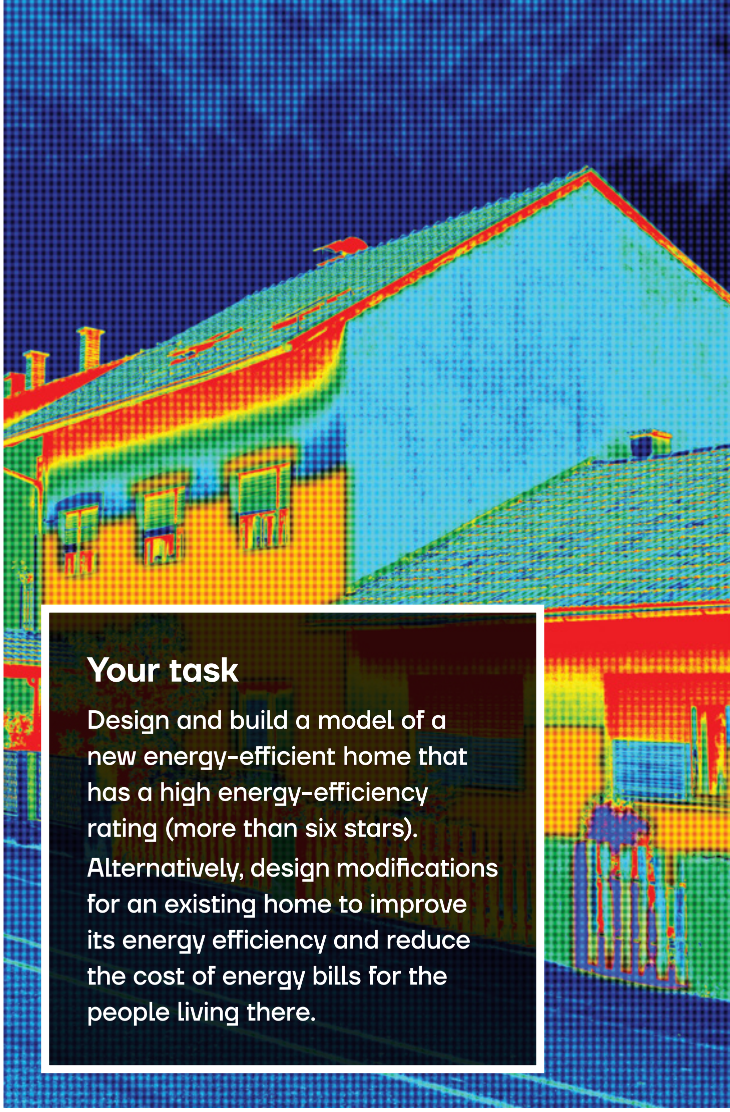
[STEAM project 1]

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.



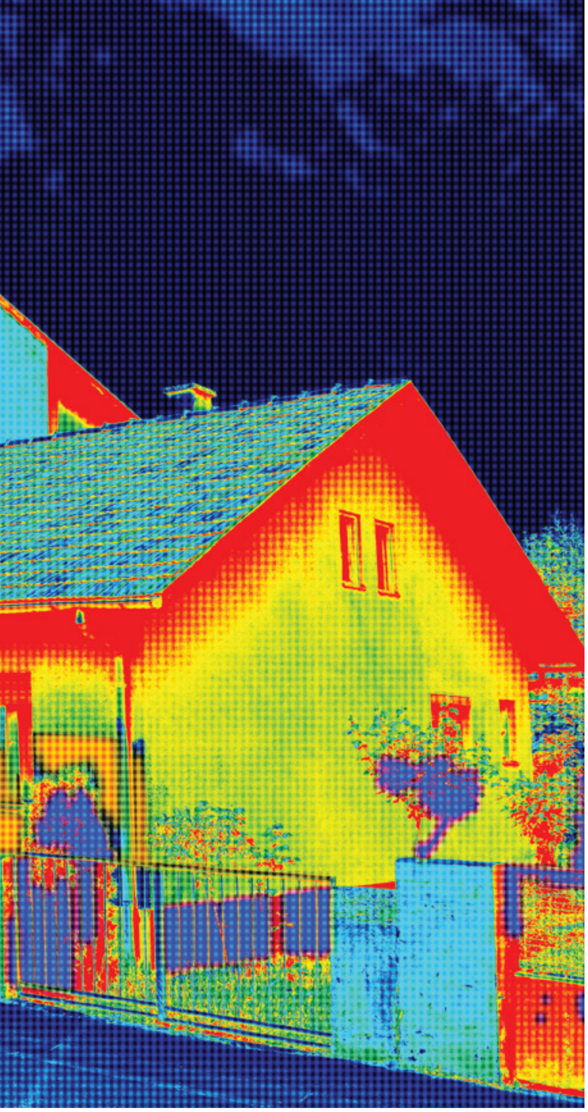
Your task

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.



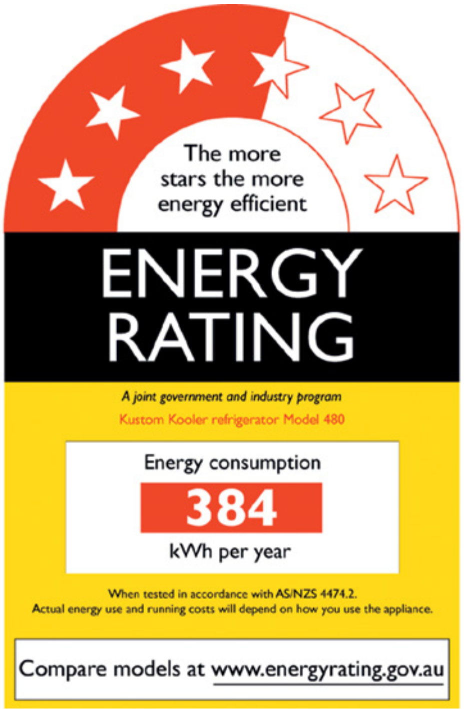


Figure 2 Energy rating schemes help consumers to understand the energy efficiency of products or appliances. The more stars, the more energy efficient the product or appliance is.

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 housing market, the interaction between businesses and consumers in meeting consumer demands and when the government intervenes in markets.

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 19 'Australian markets' of *Oxford Humanities and Social Sciences 8 Australian 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 in financial contexts. 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 'Mark-ups and discounts', 8C 'Area of quadrilaterals' and 8D 'Area of a circle' of *Oxford Maths 8 Australian Curriculum*.

SCIENCE

In Science this year, you will learn about how energy can be transferred between objects and transformed (such as from the Sun's light energy to electrical energy). You will also examine earthquake-resistant materials used in construction.

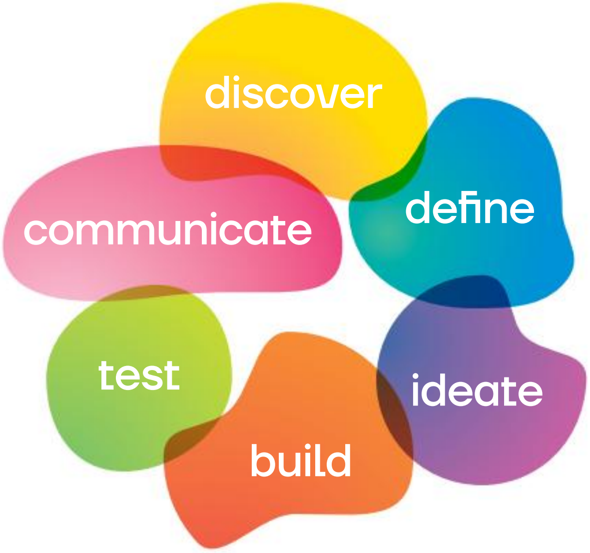
To complete this task successfully, you will need to identify how each element of a home's design can affect its heating and cooling needs, and how construction materials can affect a home's stability.

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 'Plate tectonics' and Chapter 4 'Energy' of *Oxford Science 8 Australian 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 sunlight 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 sunlight 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 booklet
This helpful booklet will guide you step-by-step through the project.

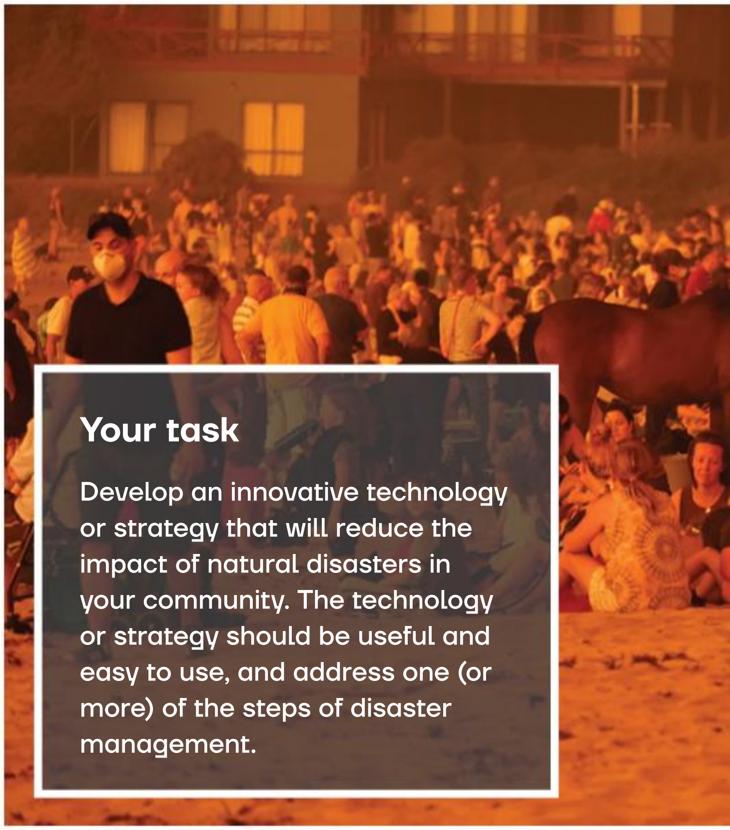
What is the design cycle?
This video will help you to better understand each phase of the design cycle.

How to manage your 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.

[STEAM project 2]

How can we use technology so that the impact of natural disasters is reduced?



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.

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 brakes 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.

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, 15, 16 and 17 of *Oxford Humanities and Social Sciences 8 Australian Curriculum*.

MATHS

In Maths this year, you will consolidate and extend your skills in describing and interpreting. 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 in financial contexts. 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 ‘Mark-ups and discounts’, 6D ‘Plotting linear relationships’, and 9A ‘Collecting data and sampling methods’ of *Oxford Maths 8 Australian Curriculum*.

Figure 2 Floodwaters near Sydney

SCIENCE

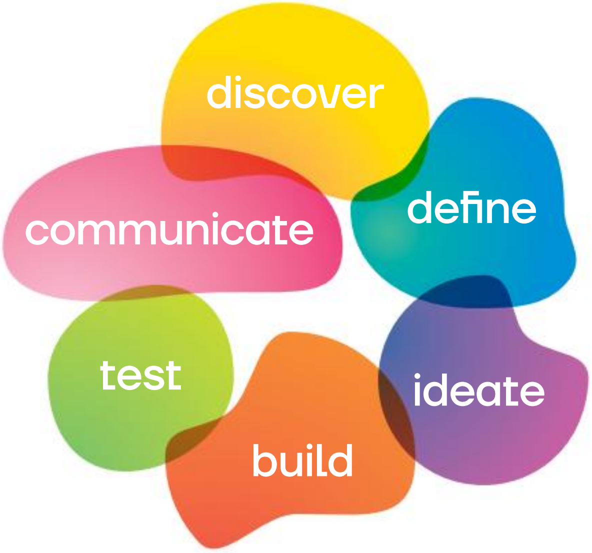
In Science this year, you will learn about how the energy of the Earth over long periods of time generates forces that can melt rocks, produce volcanoes and make diamonds. You will also learn how the kinetic energy in the air and waves can cause damage to the surrounding environments during cyclones 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 2 ‘The rock cycle’ and Chapter 4 ‘Energy’ of *Oxford Science 8 Australian 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 are needed 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 booklet
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.

GLOSSARY

A

abomasum
the fourth stomach of a cow

accuracy
how carefully, correctly and consistently data has been measured or processed; in science, how close a measured value is to the true value

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)

aorta
the major artery that carries oxygenated blood from the heart and divides into smaller arteries around the body

arteriole
smaller artery

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)

atomic theory
the theory that all matter is made up of atoms

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

biodegradable
capable of being decomposed by bacteria or other living organisms and reabsorbed into the natural environment

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

catalyst
a substance that increases the rate of a chemical reaction without undergoing any permanent chemical change

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 the cell

cell theory
theory describing the properties that all cells have in common

cell wall
the outer protective and support structure of a plant cell

cellular respiration
the chemical reaction between glucose and oxygen that produces carbon dioxide, water and energy

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

circuit diagram
a diagrammatic way to represent an electric circuit

cognitive verb
a doing word that requires you to perform a specific thinking task

collision theory
a theory stating that the particles involved in a chemical reaction must collide in order to react

colloid
a type of mixture that always looks cloudy because clumps of insoluble particles remain suspended throughout it rather than settling as sediment

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

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

continental drift
the continuous movement of the continents over time

continental shelf
a flat area under shallow ocean water at the edge of a continent

controlled variables
variables that remain unchanged during an experiment

convection
the transfer of thermal energy by the movement of molecules in air or liquid from one place to another

convection current
the current or flow of air or liquid that results from the transfer of thermal energy through convection

converging boundary
the boundary between two tectonic plates that are moving together

core
the centre of the Earth

correlation
a relationship between two or more things

corrosion
the gradual destruction of materials by a chemical reaction with their environment

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

crust
the lithosphere, or outer layer of the Earth

cytoplasm
the jelly-like fluid inside the cell membrane that contains dissolved nutrients, waste products and organelles

D

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

deposition
the process whereby sediment from different forms of weathering accumulates in layers

derived units
units of measurement that are calculated using a combination of SI (international system) base units, e.g. cm^3 for volume (base unit is cm), m^2 for area (base unit is m)

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

diverging boundary
the boundary between two tectonic plates that are moving apart

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

donor
the person giving an organ; usually deceased, sometimes living

E

elastic potential energy
the energy possessed by stretched or compressed objects

electric circuit
a closed pathway that conducts electrons in the form of electrical energy

electric current
the flow of electrical charge through a circuit

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

enzyme
a chemical that helps make chemical reactions happen; a type of catalyst

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

ethics
the series of rules that determines what is right and what is wrong

eukaryotic cell
complex cell that contains a nucleus and membrane-bound organelles

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

fault
a fracture in rock where the tectonic plates have moved

foliation
layering in a rock that occurs when the rock is subjected to uneven pressure

fossilisation
the process of an organism becoming a fossil

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

geologist
a scientist who studies rocks

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

group
(in chemistry) a vertical list of elements in the periodic table that have characteristics in common

H

hypothesis
a proposed explanation for a prediction that can be tested

I

igneous rock
rock formed by cooling magma and lava

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

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

M

magma
semi-liquid rock beneath the Earth's surface

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

mantle
the layer of molten rock beneath the Earth's crust

melt
change state from solid to liquid

metabolism
all the chemical reactions in the body

metamorphic rock
rock formed from other rock due to intense heat and pressure

microbiology
the science involving the study of microscopic organisms

microorganism
a living thing that can only be seen with the use of a microscope

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

mid-ocean ridge
a series of underwater mountains that form as a result of tectonic plates moving apart and allowing magma to rise to the surface

mitochondrion
powerhouse organelle of a cell; the site of energy production (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

N

natural flora
microbes that live happily in our bodies

negative terminal
the point in the circuit where electrons flow out from

nephron
tiny structure in the kidneys that filters the blood

nervous tissue
the group of cells that pass on electrical messages

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

ocean trench
a deep ditch under the ocean along a tectonic plate boundary

omasum
the third stomach of a cow

onion-skin weathering
weathering of rock where the outside of the rock peels off

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

outlier
a data value that is outside the range of all the other results

P

parallax error
an error, or inaccurate reading, that occurs as a result of reading a scale from an angle

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

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

plasma
a straw-coloured fluid that forms part of the blood

plate tectonics
the theory that the surface of the Earth consists of a series of plates that are continually moving due to convection, ridge push and slab pull

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

polymer
a long-chain molecule formed by the joining of many smaller repeating molecules (monomers)

positive terminal
the point in an electric circuit where electrons flow into

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

pure substance
something that contains only one type of substance (e.g. a single element or a single compound)

R

reactant
a substance used at the beginning of a chemical reaction; written on the left side of a chemical equation

reading error
an error that occurs when markings on a scale are not read correctly

reasonable experiment
a test where all variables are controlled except for the one being changed on purpose

recipient
the person receiving a donated organ

red blood cell
cell in the blood that carries oxygen around the body

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

reticulum
the second stomach of a cow

ridge push
the force pushing the edges of tectonic plates away from each other when a ridge crest has formed

rift valley
a deep valley that forms as a result of tectonic plates moving apart on land

rock cycle
the process of formation and destruction of different rock types

root
a plant organ involved in absorbing nutrients and water

rounding off
reducing the number of significant figures by increasing or decreasing to the nearest significant figure; for example, 7.6 cm is rounded up to 8 cm, 7.2 cm is rounded down to 7 cm

rumen
the first stomach of a cow

S

sea-floor spreading
the theory that the middle of the ocean is spreading apart, forming new oceanic ridges

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

SI system
an international system of measurement based on the metric system, with units such as kilogram, metre, kilometre

significant figures
the number of digits that contribute to the overall value of a number

single-celled
an organism that consists of one cell

slab pull
the force pulling a tectonic plate beneath a less dense tectonic plate

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

solution
a mixture of a solute dissolved in a solvent

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

stain
substance, such as iodine, used to make cells more visible under a microscope

stem
an organ that transports materials around a plant

stereomicroscope
a microscope with two eyepieces that uses low magnification

subduction
the movement of one tectonic plate under another tectonic plate

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

suspension
a cloudy liquid containing insoluble particles

symptoms
the physical or mental signs of a disease

system
a group of organs that work together for a purpose

T

tectonic plate
a large layer of solid rock that covers part of the surface of the Earth; movement of tectonic plates can cause earthquakes

thermal energy
the scientific term for heat energy

tor
a large, round rock produced by onion-skin weathering

trace fossil
traces of an organism that existed in the past

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

transforming boundary
the boundary between two tectonic plates that are sliding past each other

transpiration
the process of water evaporating from plant leaves; causes water to move up through the plant from the roots

tsunami
a series of large waves that result from an underwater earthquake

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

urea
a chemical waste product produced by the body and removed in the urine

V

valid experiment
where an experiment investigates what it sets out to investigate

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

vascular bundle
a group of tubes in plant stems that carry water and nutrients around the plant

vein
a thin-walled blood vessel that carries blood back to the heart

ventricles
the two large lower chambers of the heart

vesicle
an organelle surrounded by a membrane and used by cells to store materials; a vacuole is a type of vesicle found in plant cells

villi
small ridges in the small intestine that absorb nutrients from the digestive system

volatile
describes a substance that easily becomes a gas

W

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

zero error
an error that occurs when an instrument has not been adjusted to zero before the measurement is taken

INDEX

Notes

Notes

Notes

If you could journey deep inside the Earth, you would find that it is made of several layers. We live on the outer layer, the Earth's crust, which is made up of broken pieces called tectonic plates. The movement of these plates can create land formations such as mountains, ocean trenches and volcanoes. This image shows a volcano erupting with semi-liquid rock called magma. Once magma has erupted it is called lava.

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contact customer support at **oup.com.au/help**