GRAEME LOFTS | MERRIN J. EVERGREEN

JACARANDA

SCIENCE QUEST 8

VICTORIAN CURRICULUM | THIRD EDITION

VICTORIAN CURRICULUM v2.0

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All activities in this resource have been written with the safety of both teacher and student in mind. Some, however, involve physical activity or the use of equipment or tools. **All due care should be taken when performing such activities**. To the maximum extent permitted by law, the author and publisher disclaim all responsibility and liability for any injury or loss that may be sustained when completing activities described in this resource.

The publisher acknowledges ongoing discussions related to gender-based population data. At the time of publishing, there was insufficient data available to allow for the meaningful analysis of trends and patterns to broaden our discussion of demographics beyond male and female gender identification.

Contents

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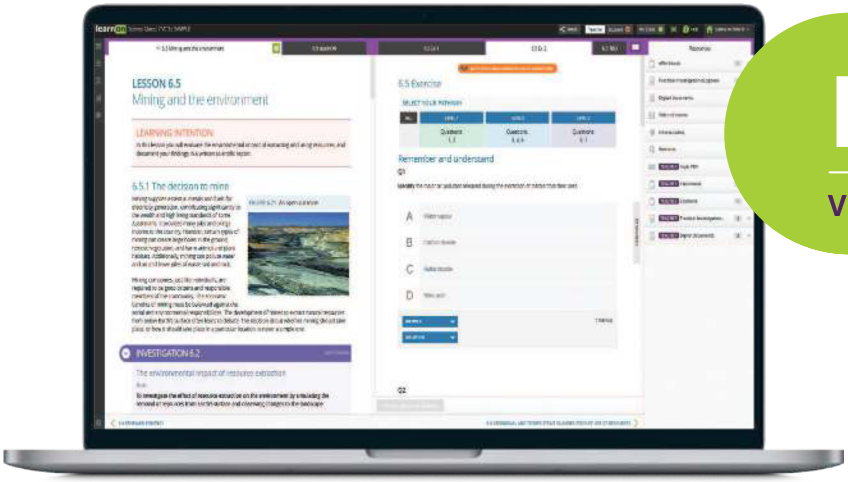

NEW FOR

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JACARANDA

SCIENCE QUEST 8 VICTORIAN CURRICULUM

THIRD EDITION

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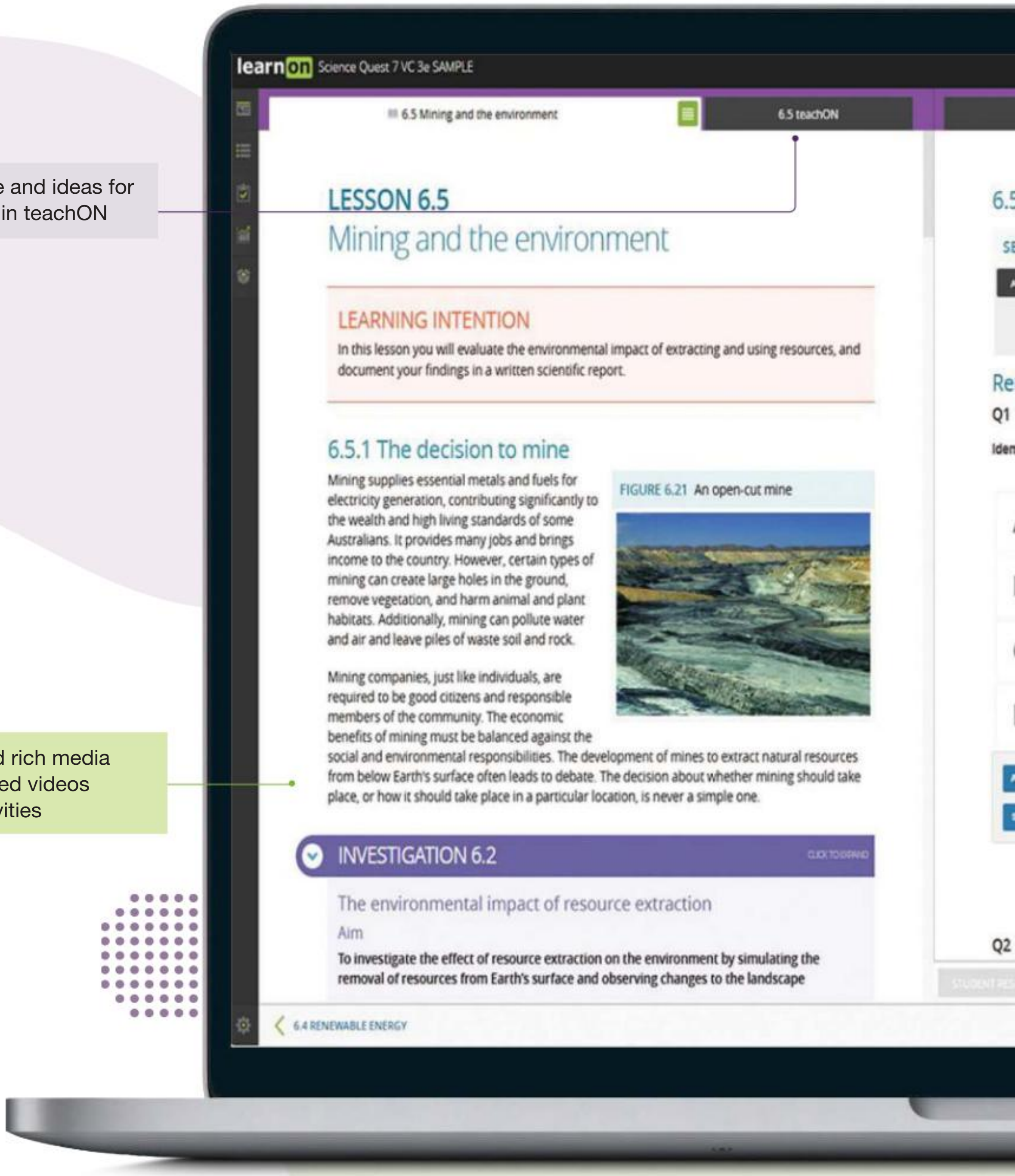

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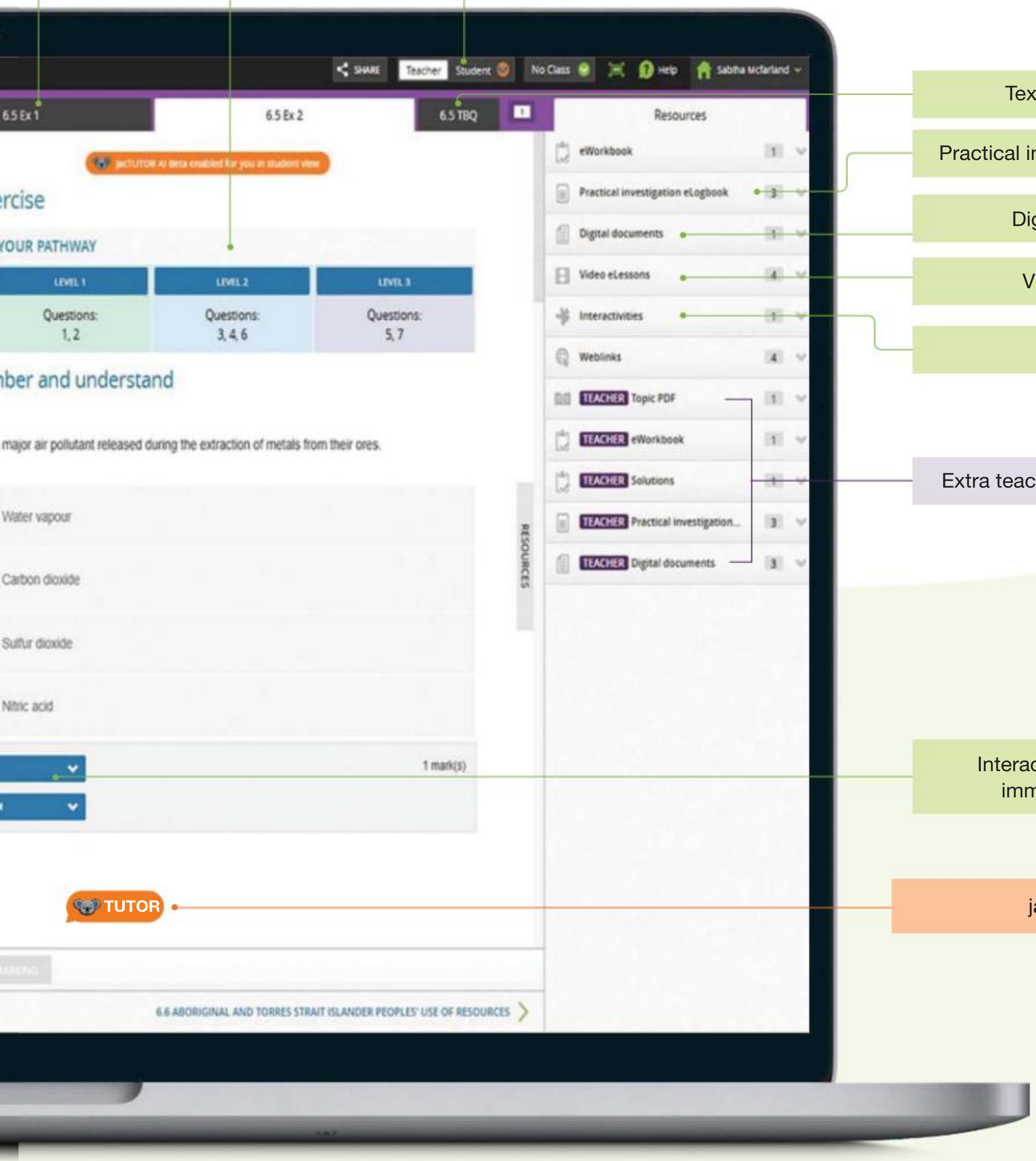

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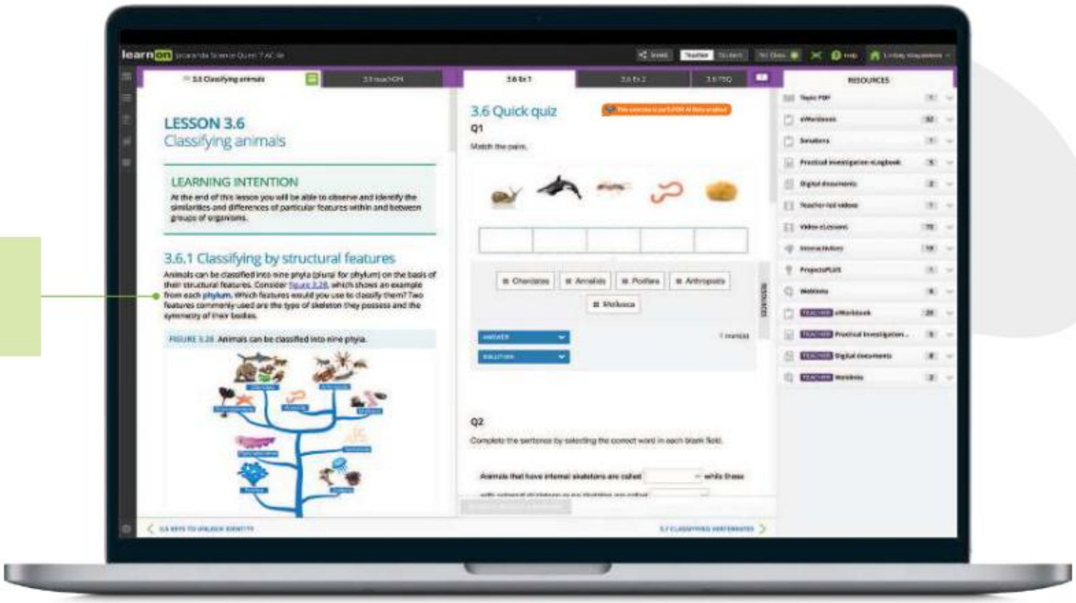

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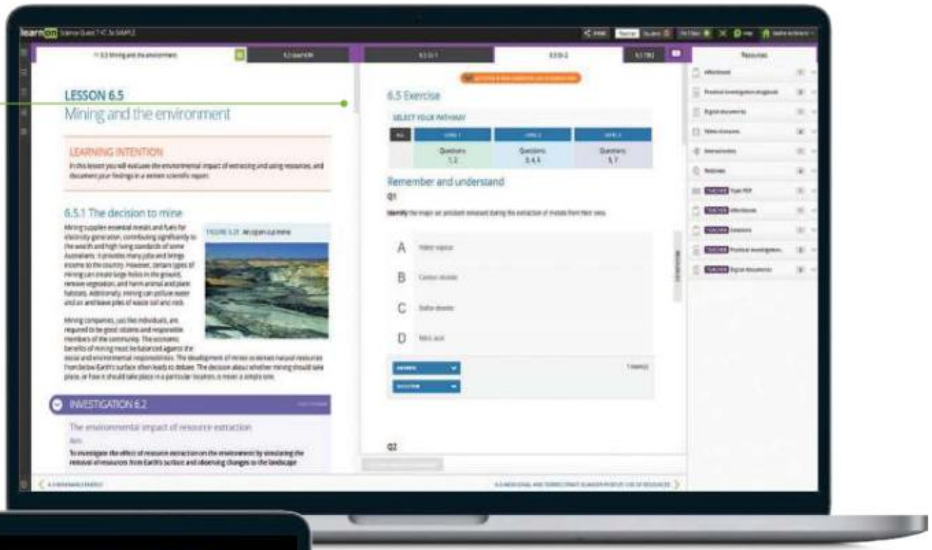

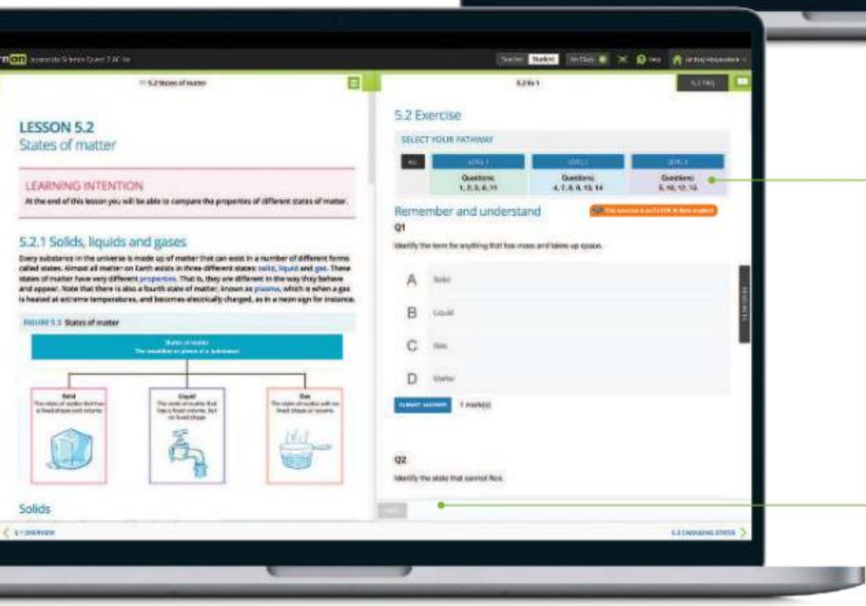

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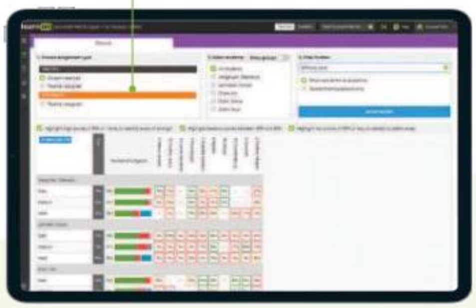

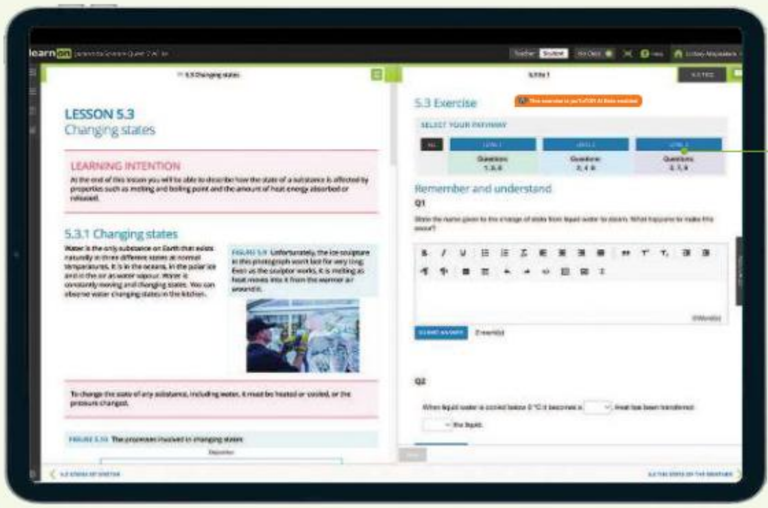

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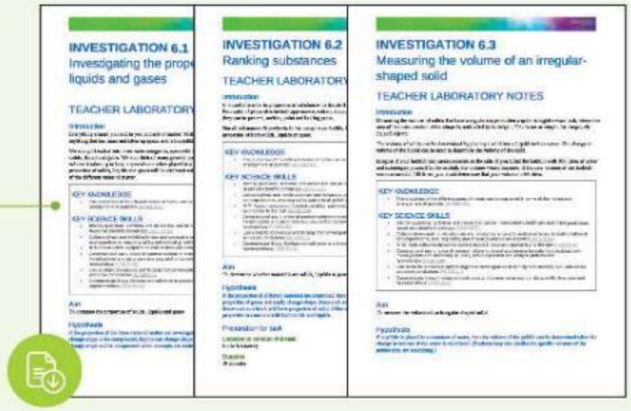
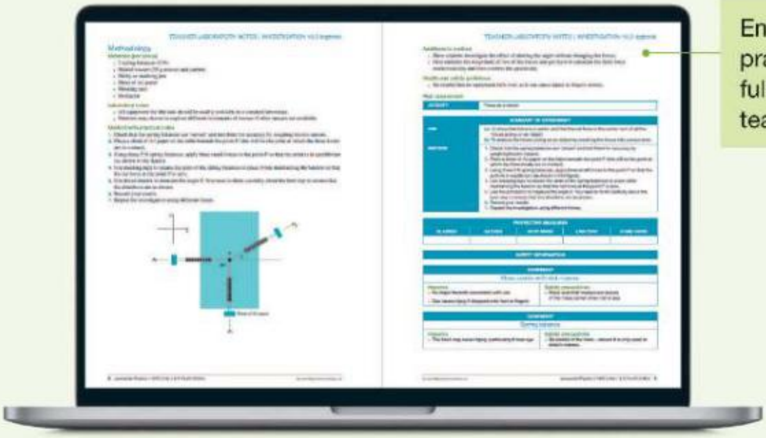
The **practical investigation eLogbook** ignites curiosity through science investigation work, with an extensive range of exciting and meaningful practical investigations. Aligned with the scientific method, students can develop rich science inquiry skills in conducting scientific investigations and communicating their findings, allowing them to truly think and act like scientists! The practical investigation eLogbook is supported with an unrivalled teacher and laboratory guide, which provides suggestions for differentiation and alteration, risk assessments, expected practical results and exemplary responses.

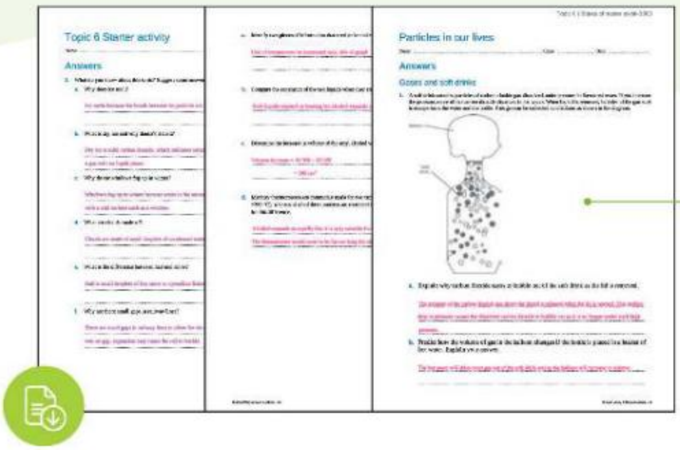


Risk Assess Included



Enhanced practical investigation support includes practical investigation videos and an eLogbook with fully customisable practical investigations — including teacher advice and risk assessments.

eWorkbook



The **eWorkbook** is the perfect companion to the series, adding another layer of individualised learning opportunities for students, and catering for multiple entry and exit points in student learning. The eWorkbook also features fun and engaging activities for students of all abilities and offers a space for students to reflect on their own learning. The new eWorkbook and eWorkbook solutions are available as a downloadable PDF or a customisable Word document in learnON.

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- three levels of differentiated teaching programs
- quarantined topic tests (with solutions)

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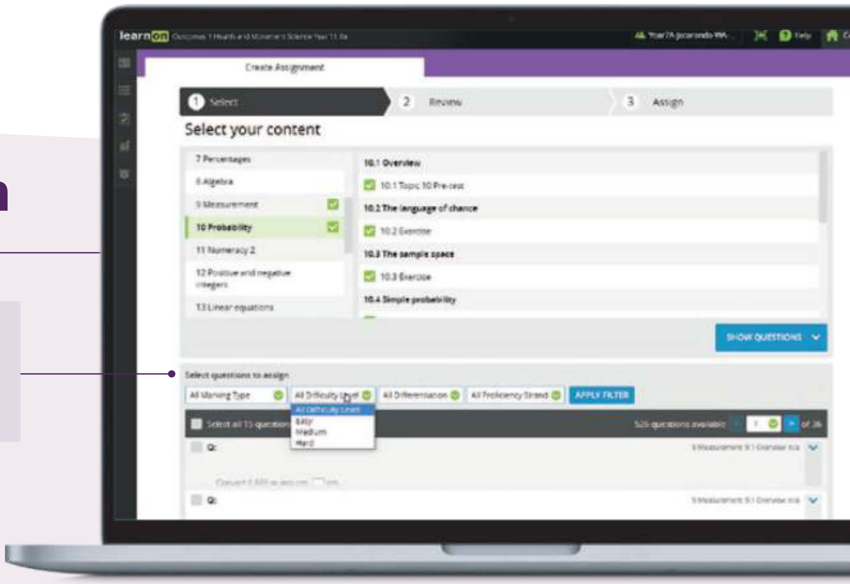

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Data analytics and instant reports provide data-driven insights into progress and performance within each lesson and across the entire course.

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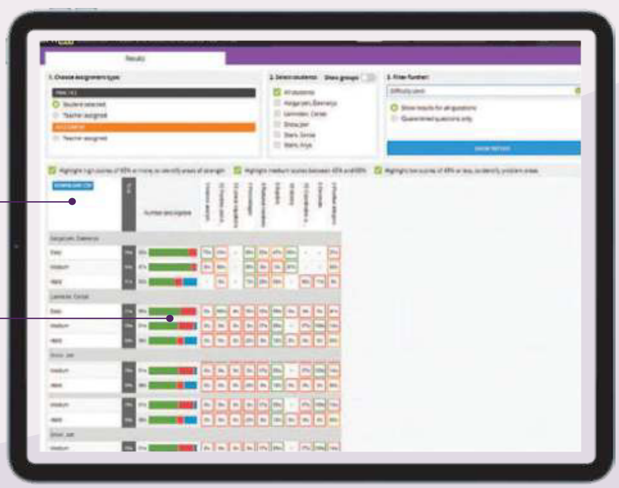


The new jacTUTOR

Help when students (and teachers) need it — with jacTUTOR

With jacTUTOR, every student can have the help of a personal tutor when they get stuck, in class or at home. This purpose-built tool sits safely within your favourite Jacaranda resource, so guidance will always be specific to that lesson, question and curriculum.

A personal tutor for every student

Now every student can get the help they need, when they need it. jacTUTOR uses AI to create a fair and level playing field for all students.

Get guidance, not the answer

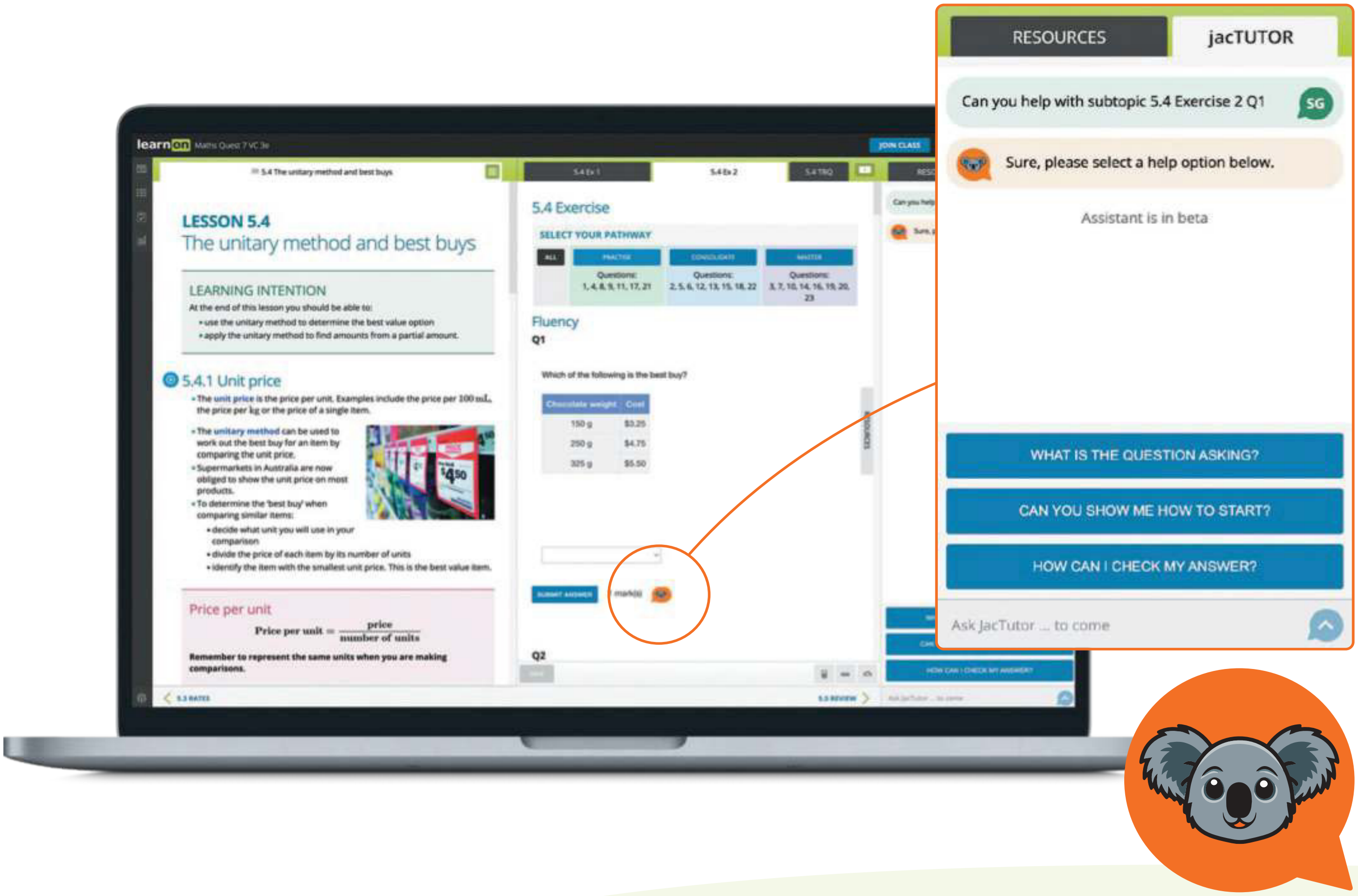
jacTUTOR doesn't just give the answer away. Students are given prompts to help understand what they should be asking to get to a correct answer.

Combat anxiety

Afraid to raise a hand or ask more questions? With jacTUTOR, students will find a safe space to ask questions, get clarification and try again.

A safe space

To keep students safe, any concerning or inappropriate comments are automatically flagged and sent to their teacher.



Meet our author team

Graeme Lofts

Graeme taught Physics, Science and Mathematics at both government and independent schools in Victoria for more than twenty-three years. He has also lectured in Science Education at the University of Melbourne and RMIT University. During his career in science education, Graeme has been honoured with many awards, including an International Teaching Fellowship and the BHP Science Teacher Award.

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Merrin J. Evergreen, PhD, is a distinguished author and educator in the field of science education. With a passion for making science accessible and engaging, Dr Evergreen has contributed to a number of educational texts that are widely used in Australian schools. Her dedication to science education is evident in the clarity and depth of her publications, making complex scientific concepts understandable for students at various levels of their academic journey. Dr Evergreen's commitment to education extends beyond her writing, with a history of active involvement in educational initiatives and endeavours to enhance science literacy.

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Catherine Bellair is an experienced VCE Physics, Science, Mathematics and STEM educator with over 20 years of teaching experience. She is very involved in the science teaching community, often presenting at conferences in addition to being on the board of the Science Teachers Association of Victoria (STAV). Her teaching interests include improving both science literacy and general literacy as it applies to science, and improving student access to STEM learning opportunities in secondary schools. Her qualifications include a Bachelor of Science, a Graduate Diploma of Education, a Certificate in Education (STEM) and a Masters of Education (Student Wellbeing).

Daniela Carboon

Daniela Carboon is a passionate educator dedicated to making science engaging and accessible for all learners, inspiring students to develop a lifelong love for the subject. With over 15 years of experience teaching Chemistry, Science and Mathematics, she has authored chapters in science textbooks and held leadership roles, including Learning Leader in Science and Technology. Daniela holds a Bachelor of Applied Science in Chemistry and a Diploma of Education in Secondary Education. Her experience in the science industry, including work as an Analytical Chemist, informs her ability to foster curiosity, critical thinking and a deeper understanding of scientific concepts in her students.

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Dr Lucy Cassar is a distinguished VCE Biology, Science and STEM educator with 15 years of experience. She is currently the Vice President of the Science Teachers Association of Victoria (STAV) and is committed to advancing science and STEM education. Her qualifications include a Bachelor of Science, a Bachelor of Biomedical Science (Honors), a Diploma of Education, and a PhD from Monash University.

Ian Hoffman

Throughout his teaching career, Ian Hoffman has branched out from his studies in Physics to explore every dimension of STEM. In recent years, a particular focus on the Engineering and Technology aspects has led to an interest in how schools can use modern manufacturing techniques to rapidly prototype and develop controlled autonomous systems.

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Nicole Cox is an accomplished Geologist with over 10 years of experience in tertiary education, including delivery of STEM subjects for future educators. Nicole is currently a Principal Structural Geologist for a mining and exploration company, where she supports and mentors teams across Australia. Nicole holds a Bachelor of Science and a Master of Science in Geology from Brigham Young University, Provo, Utah, USA.

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Nick Fitzgerald is a high school Science teacher with 30 years of classroom experience across three countries and two continents. He has taught in public and private school settings, as well as hospital school settings, including classes for academic and behavioural support, medical support and academic extension. Nick is currently teaching curriculum to students within a specialist health care setting. His qualifications include a BSc (Hons) in Aquatic Bioscience from the University of Glasgow, Scotland, and a Post Graduate Certificate of Education from the University of Strathclyde, Scotland. Nick is passionate about making the curriculum as accessible, engaging and achievable as possible for all students.

Robert Stokes

Robert Stokes is a retired chemistry and science teacher with over thirty-five years of experience teaching secondary school students and mature-age students. He has also worked on several projects including Science Teachers Association of Victoria (STAV) trial tests and Australian Council for Education Research (ACER) diagnostic tests. Robert has served on the former Technical Schools Examination Board as well as statewide chemistry committees. His qualifications include a Bachelor of Science and a Diploma of Education.

Luke Williams, Gumbaynggirr

Dr Luke Williams is a proud Gumbaynggirr man of Northern NSW. Luke is a researcher who primarily focuses on the traditional uses of native Australian plants with an emphasis on understanding how these traditional plants can contribute to our modern food and medicine systems. Aside from experimenting with these plants, Luke brings together Indigenous knowledge holders with Western science to explore how these two knowledge systems can add value to our society. Luke is passionate about empowering the next generation of scientist to think holistically about their research.

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The full list of acknowledgements can be found here:
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Understanding command terms in the Victorian Curriculum

The Victorian Curriculum aims to develop students' disciplinary knowledge, skills, understanding and general capabilities across the curriculum. Students are also expected to progressively develop their thinking skills.

In the Victorian Curriculum, command terms are used as signposts for this depth of thinking. Command terms signify different types of thinking and are already used in the classroom by many teachers and students.

Questions within Jacaranda resources use these command terms to support students in command terms 'thinking'.

For a full list of the command verbs used throughout the Science Quest series, visit learnON.

1 Investigating science

LESSON SEQUENCE

LESSON 1.1 Overview

1.1.1 Introduction

Science helps us learn about the world. When we do science, we discover new things. To practise science, we follow certain steps and use special skills to answer questions and solve problems.

First, we observe the world around us using our senses and tools such as microscopes and telescopes. Observing can also mean measuring things.

Observations make us curious and lead to questions and ideas (hypotheses). To find answers, scientists create investigations and experiments.

Investigations can change one thing (the **independent variable**) to see what happens to another thing (the **dependent variable**). Everything else stays the same to keep the experiment fair. Scientists repeat experiments to make sure the results are reliable.

Experiments give us **data**, which is information that we can organise in tables or graphs for studying or analysing. We might use calculations to find averages or ranges. By looking at the data, we can identify patterns and draw conclusions.

Sometimes, the results support our ideas, answer our questions and solve problems. At other times, they lead to new questions and more experiments. This is how we keep learning new things about the world.

In this topic, we will learn more about scientific practices and use these skills.

DISCUSSION

1. Why should scientists test only one variable at a time? How does this improve the reliability of results?
2. How has scientific investigation improved products or solved problems in everyday life?
3. What ethical considerations are important when researching living organisms or culturally significant sites?
4. What should scientists do if experiment results do not match their hypothesis? Why is this important for scientific progress?
5. How do tables, graphs and models help scientists communicate their findings effectively?
6. In an experiment testing water temperature and plant growth, what variables need to be controlled, and how should the data be organised?

SCIENCE INQUIRY: Testing the effects of fertiliser on crop growth

Imagine you are a scientist investigating how fertiliser affects the growth of wheat crops. Farmers want to know the best fertiliser to use for their fields to maximise yield. To test this, you could design an experiment following the steps of scientific inquiry.

Identify the variables

- Independent variable: The type of fertiliser — organic, chemical and no fertiliser
- Dependent variable: The growth of the wheat, measured by the height of the plants or the weight of the harvest
- Controlled variables: Soil type, water, sunlight and the amount of fertiliser used for each plot

Set up the experiment

Divide a field into three equal sections, one for each type of fertiliser. Plant wheat seeds in each section under the same conditions. Apply the fertilisers as per their instructions and ensure each plot receives the same amount of water and sunlight.

Collect and record data

Over time, measure the height of the plants weekly. At harvest, weigh the grain yield from each plot. Record these observations in a table to track differences between the groups.

Organise and analyse the data

Create a bar graph to compare the average plant height and yield for each type of fertiliser. Look for patterns: which fertiliser resulted in the tallest plants or the highest yield?

Draw conclusions

Based on your analysis, determine which fertiliser had the most significant positive effect on the crop. If no fertiliser performed well, consider whether another factor, such as soil type, influenced the results.

Evaluate and communicate findings

Share your results with other scientists and farmers. Repeating the experiment in different locations or with other crops can validate your findings.

1. What is the independent variable in this experiment, and why is it important to test one variable at a time?
2. List three controlled variables in this experiment and explain why they need to remain the same.
3. What tools and methods could be used to measure plant growth and crop yield accurately?
4. Why is it useful to create graphs or tables when comparing the effects of different fertilisers?
5. If the organic fertiliser produced the highest yield, but it was also the most expensive, how might this influence a farmer's decision?
6. How would you address an anomaly, such as one plot showing unusually low growth despite receiving fertiliser?
7. What ethical practices should be followed to ensure this experiment does not harm the environment?
8. Why is it important to conduct this experiment in a way that respects cultural practices and protocols, especially if the land used has cultural significance?

Reproducible investigations to answer questions and test hypotheses can be planned and conducted, including identifying independent, dependent and controlled variables where applicable, stating assumptions, recognising and managing risks, considering ethical issues and following protocols when accessing cultural sites and artefacts on Country and Place (VC2S8I02)

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Pre-test	Topic 1 Pre-test
eWorkbooks	Topic 1 eWorkbook Student learning matrix
Practical investigation eLogbook	Topic 1 Practical investigation eLogbook
Digital document	Key terms glossary

LESSON 1.2 Observing

LEARNING INTENTION

In this lesson you will:
- make observations using your senses
- measure quantities, including length, mass, temperature and volume, using appropriate scientific equipment.

1.2.1 Using the senses

Making observations involves using your senses to collect information.

TABLE 1.1 Understanding the five senses

Sense	Sense organ	Type of information collected
Sight	Eye	Colour, shape, movement, text, measurements
Hearing	Ear	Sounds including speech, music, beeps, etc.
Touch	Skin	Texture, temperature, shape
Taste	Tongue	Tastes such as sweet, sour and salty. (*Note:* This sense is rarely used in science experiments.)
Smell	Nose	Pleasant and unpleasant odours, as well as odours that can be used to identify particular substances

FIGURE 1.1 Your five senses help you collect information.

INVESTIGATION 1.1

Using your senses to make observations

Aim

To use our senses to investigate some chemical changes

Safety

- In this investigation, you will NOT be using the sense of taste to make observations.
- Goggles should be worn to carry out this investigation.
- Do not touch any of the chemicals.

Materials

- 3 test tubes
- dilute (1.5 mol/L) sulfuric acid
- matches
- small piece of magnesium
- thermometer
- vinegar
- sodium bicarbonate powder
- dilute (0.5 mol/L) copper sulfate solution
- steel wool
- kettle
- beaker

Method

Part 1

1. Fill a test tube to $\frac{1}{3}$ full with dilute sulfuric acid.
2. Feel the outside of the test tube and measure the temperature of the acid with a thermometer.
3. Add a small piece of magnesium. Collect the gas produced by placing another test tube over the top of the test tube containing the acid.
4. Another student should light a match.
5. Quickly remove the top test tube and place the match under it, to light the gas that has collected in the test tube.
6. Feel the outside of the test tube and measure the temperature of the acid with a thermometer again.

Part 2

1. Fill a test tube to $\frac{1}{3}$ full with vinegar. Measure the temperature of the vinegar.
2. Add a spatula full of sodium bicarbonate powder.
3. Observe the reaction and measure the temperature of the test tube again.

Part 3

1. Fill a test tube to $\frac{1}{3}$ full with copper sulfate solution.
2. Prepare a water bath by filling a beaker with hot water from a kettle. **Caution:** Fill the beaker at your bench, rather than carrying the beaker full of hot water around the laboratory.
3. Heat the copper sulfate by placing the test tube in the water bath.
4. When the temperature of the copper sulfate has reached at least 50 degrees, remove the test tube from the water bath and record the exact temperature of the copper sulfate.
5. Add a small wad of steel wool to the copper sulfate.
6. Record your observation and measure the temperature of the solution after the reaction has finished.

Results

Record your results in a table like the one below.

Reaction	Initial temperature (°C)	Final temperature (°C)	Observations
Magnesium + acid			
Vinegar + sodium bicarbonate			
Copper sulfate + steel wool			

Discussion

1. Which senses did you use in this experiment to collect results?
2. What is the advantage of using a thermometer rather than just feeling the outside of the test tube to collect information about temperature?

Conclusion

Complete the conclusion below.

The sense of _________________ is most useful to observe colour changes and the appearance and disappearance of substances in chemical reactions. We can also use the sense of ________________ to detect changes in temperature and the sense of ____________ to identify sounds produced in chemical reactions.

1.2.2 Measuring quantities

In investigation 1.1, we saw that a thermometer provides a better indication of temperature than just feeling the outside of the container. A thermometer provides a quantitative measurement of temperature, whereas feeling whether the **test tube** is hot or cold is a qualitative observation of temperature.

KEY IDEA

- **Qualitative data** examines the quality of something but does not include measurements. Examples of qualitative observations include: description, colour, shape, seeing that a gas has been produced or the feeling of warmth from a test tube.
- **Quantitative data** examines the quantity of something, so it includes measurements. Examples of quantitative observations include: a temperature reading, length and mass, the volume of gas produced or the wavelength of light produced.

1.2.3 Precise measurements

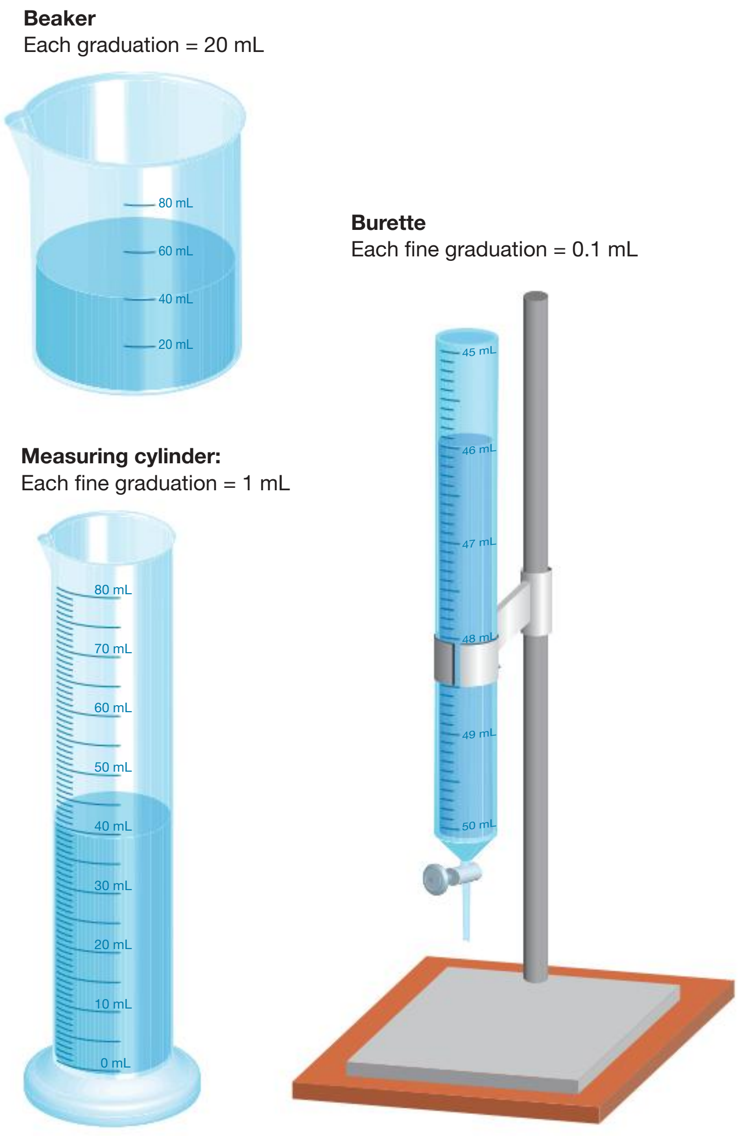
The term **precision** relates to how close multiple measurements in the same investigation are to one another. The degree of precision of the measurements taken in an experiment depends on the instruments that have been used. If you want to measure the length of your classroom, you could also use a trundle wheel with marks every 10 cm, or you could use a tape measure marked in millimetres. The tape measure would provide the most precise measurement. Similarly, to measure 100 mL water, you could use a **measuring cylinder** that is graduated in millilitres or you could use a measuring cup that is marked every 100 mL. The measuring cylinder would provide a more precise measurement than the cup. A set of scales that measures mass to 2 decimal places is more precise than one that measures mass to 1 decimal place.

1.2.4 Accurate measurements

Accurate measurements are not only precise but also correct. A small measuring cylinder can provide a reasonably precise measurement of a volume of water but, if it is not read at eye level, the measurement may not be accurate. A set of bathroom scales might display a reading with 2 decimal places but, if you use it on carpeted floor, it may not provide an accurate measurement of your mass if it is designed to be used on a hard floor.

To ensure that your results are accurate, you should use measuring instruments correctly and in some instances it may be necessary to **calibrate** the instruments, which means to check or adjust an instrument to ensure accurate measurements. To calibrate a set of scales, for example, you could place an object that has a mass of exactly 100 g on the scale and adjust the scale until it reads exactly 100 g. A poorly designed method can also affect the **accuracy** of the results, that is, how close experimental results are to a known value, particularly if **variables** have not been properly controlled.

FIGURE 1.2 Which piece of equipment provides the most precise measurement?



1.2.5 Observation or inference?

After making observations, you might make an inference. An inference involves providing a possible explanation for the observations. For instance, you might observe that the side of a car is damaged and infer that the car was involved in an accident. Inferences do not always turn out to be correct.

KEY IDEA

- We make observations using our senses. Observations do not involve explanations or interpretations. We just record what we see, hear, feel, taste or smell.
- An inference is an explanation or interpretation of the observations.

1.2 Activities

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1.2 Quick quiz on	1.2 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 5, 6	3, 4, 7, 8	9, 10

Remember and understand

1. MC **Identify** which sense is not usually used to make observations in science.
   A. Sight
   B. Hearing
   C. Touch
   D. Taste
2. Student A feels the outside of a test tube and notices that it is warm. Student B records the temperature of the substance inside the test tube with a thermometer. They record that the temperature is 65 °C.
   a. **State** whether Student A's observation is quantitative or qualitative.
   b. **State** whether Student B's observation is quantitative or qualitative.
3. Use an example to **distinguish** between qualitative and quantitative observations.
4. MC A scientist has an object that has a mass of exactly 100 g. They place the object on the scales in their lab and it reads 105.1 g.

   Identify what this indicates.
   A. The scale is not precise.
   B. The scale is not reliable.
   C. The scale needs to be calibrated.
   D. The scale doesn't work and needs to be thrown out.

Apply and analyse

5. A student places a piece of magnesium in some acid. The student writes the following observations:
   - A gas is produced.
   - The temperature of the acid increases.

   The student collects some of the gas and places a lit match in the gas. A 'pop' sound can be heard.

   State which senses the student has used to make their observations.

6. **MC** A student uses a metre ruler to measure how far a toy car has travelled. **Name** the sense the student is using to make this observation.
   A. Sight
   B. Hearing
   C. Touch
   D. Smell
7. When baking, Mr Zhang uses a measuring cup to measure the amount of oil that needs to go into his chocolate cake. The measuring cup has graduation lines that are 50 mL apart.

   In the laboratory, Mr Zhang uses a measuring cylinder to measure the oil he needs to add to his experiment. The graduation lines on the measuring cylinder are 1 mL apart.

   The measuring cylinder is a more _______________ measuring tool than the measuring cup.
8. Read the following statements and **state** whether each sentence is an observation or an inference.

Statement	Observation	Inference
a. The dog in the house next door is barking.		
b. There are no lights on in the house.		
c. The owners must be asleep.		
d. There could be a prowler in the backyard.		
e. I heard the sound of breaking glass.		

Evaluate and create

9. Bathroom scales are designed to be used on a hard surface such as tiles or a wooden floor. A student would like to find out the type of error that will result if bathroom scales are used on carpet. Will the scales consistently give a reading that is less than the actual value and by the same amount, or will the size and direction of the error vary? **Explain** your answer.

   Construct an investigation to find the answer to the student's question.
10. **List** key points that could be included on a poster to help Year 8 students understand the difference between accuracy and precision, using a measurement of length as an example. Once complete, design the poster.

Answers and sample responses are available in your digital formats.

LESSON 1.3 Measuring and reading scales

LEARNING INTENTION

In this lesson you will read and record measurements accurately.

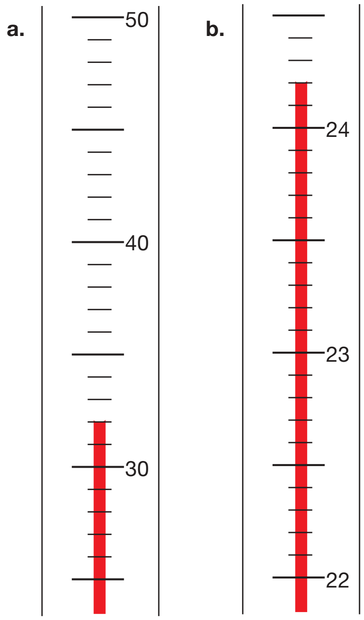
1.3.1 Why do we need to measure and read scales?

When conducting experiments, it is critical that measurements and data are recorded accurately. Whether we are measuring volume or temperature, or interpreting alternate scales, it is important that we record our results correctly.

What is the application of measuring and reading scales in science?

In science applications, measuring and reading scales are used to observe and record many variables including volumes of liquids or gas, mass, length and temperature. It is important that scales are used correctly to reduce random errors and ensure that the data obtained is accurate, in order to reach **valid** conclusions.

FIGURE 1.3 The temperatures measured by thermometers a. and b. are 32 °C and 24.2 °C, respectively.



1.3.2 How do we measure and read scales?

Materials

- thermometer with a liquid column (alcohol or mercury)
- 250-mL measuring cylinder or burette

Method

Step 1

Ensure the thermometer has a marked scale. Find the top of the measuring column and position your eye so that it is level with the top of the column. This will avoid any parallax errors in reading the temperature. Read the number on the largest scale division below the top of the column.

Step 2

Identify the largest scale division above the top of the column. Count the divisions between the upper and lower scale marks. Divide the number of divisions into the temperature difference between the upper and lower scale divisions. This will give you the amount each scale division is worth. Count up from the lower scale division and read the correct temperature. If the column is in the middle of two divisions, the reading will be half a scale division above the lower reading.

Step 3

Liquids in containers such as measuring cylinders often form a curved surface at the top edge. The curve is called a meniscus. The edges of the meniscus may curve up or down. Locate the middle flat section of the meniscus and position your eye so it is level with it.

Step 4

Using the procedure in step 2, read the volume of the middle flat section of the meniscus.

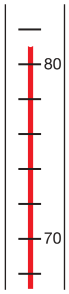
1.3 Activities

learnon

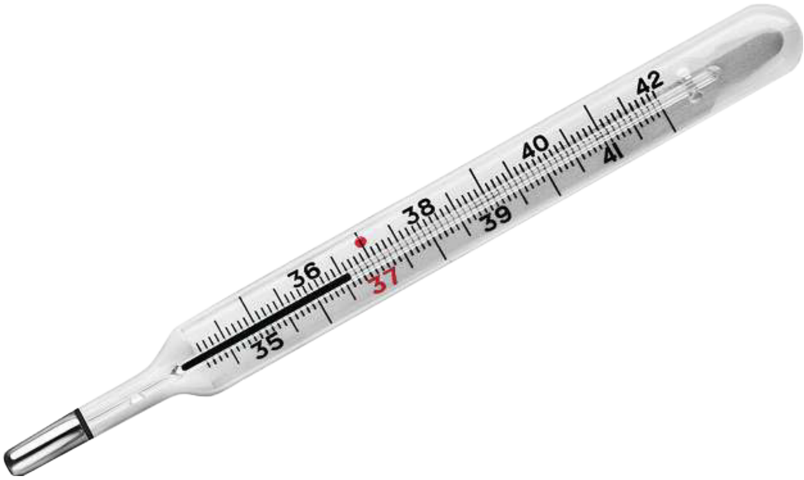
1.3 Quick quiz on	1.3 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 4	–	–

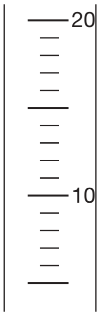
1. The diagram shows a portion of a thermometer measuring a temperature in degrees Celsius.
   a. **Identify** the value of the lower scale marker.
   b. **Identify** the value of the higher scale marker.
   c. **Calculate** the value of each scale division.
   d. **Identify** the reading of the red column of the thermometer.



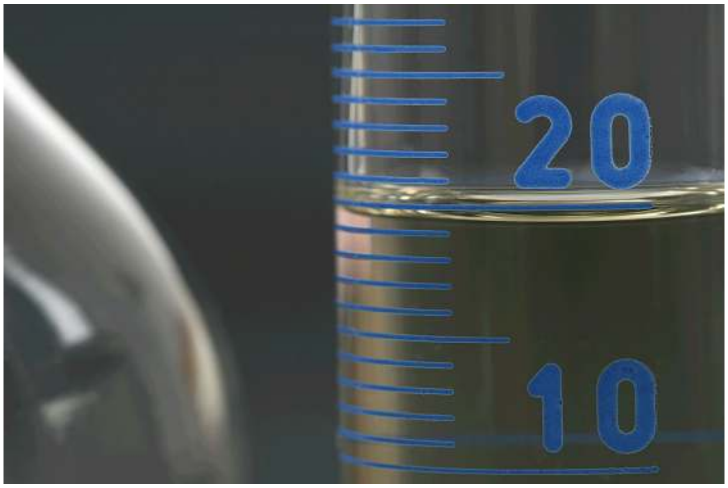
2. Human body temperature is normally around 37 °C. If a person's temperature is different from that, they may be suffering an illness. The thermometer below shows the temperature of a patient.



   Identify the temperature that is shown.
3. The diagram represents a section of an alcohol thermometer. Copy the figure and draw a central line to show a temperature of 14 °C.



4. The image shows a measuring cylinder containing some water.



Read the scale to determine the volume of water in the measuring cylinder.

a. MC **Identify** the correct reading.

A. 19.5 mL
B. 20.5 mL
C. 21.0 mL
D. 22.0 mL

b. **Explain** how you reached your answer.

Answers and sample responses are available in your digital formats.

LESSON 1.4 Questioning and predicting

LEARNING INTENTION

In this lesson you will:

- identify questions and problems that can be investigated scientifically
- make predictions based on scientific knowledge and observations.

1.4.1 Coming up with a problem

In science, investigations allow us to explore questions, test ideas and better understand the world around us. Each year, students are expected to design, carry out and report on practical investigations. These projects develop critical thinking, problem-solving and communication skills, which are essential for scientific inquiry.

Choosing a problem to investigate can be one of the most challenging and exciting parts of the process. Ideally, your investigation should focus on a question or problem that interests you. The question should be written in a way that allows for a clear **hypothesis** to be tested through a scientific experiment. Essentially, a hypothesis is a **testable** explanation for observations or experimental results. It can act as a prediction for an investigation.

A good scientific investigation question:

- relates to a scientific concept or principle
- challenges you to learn something new
- is achievable with the resources and time available at school.

To ensure success, think carefully about the materials, equipment and time required to carry out your investigation. It is important to choose a question that is manageable within these constraints. For example, experiments involving simple materials such as water, plants or household items are often more practical than those requiring advanced equipment or chemicals.

Here are a few examples of questions suitable for a Year 8 science investigation:

- How does the amount of sunlight affect the growth of a plant?
- What type of material is most effective at insulating heat?
- How does the concentration of salt in water affect its freezing point?
- What is the effect of temperature on the rate at which sugar dissolves in water?

The process of scientific investigation involves the following tasks.

- *Identifying the problem:* clearly defining the question you want to investigate
- *Formulating a hypothesis:* making a prediction based on your understanding of the topic
- *Designing the experiment:* planning how to test your hypothesis, including identifying variables and ensuring the experiment is fair
- *Carrying out the experiment:* collecting data using accurate and precise measurements
- *Organising and analysing data:* using graphs, tables and models to identify patterns or trends
- *Drawing conclusions:* reflecting on the data to determine whether it supports your hypothesis
- *Communicating findings:* sharing your results in a clear and logical format

Investigations are an essential part of learning science, helping students develop their skills while exploring topics of personal interest. By following these steps, you can conduct meaningful experiments and contribute to your understanding of the **scientific method**.

Possible topics

- Does the thickness of a rubber band affect how far it stretches? Do other features of rubber bands affect how far they stretch?
- What type of paper aeroplane flies furthest?
- What type of parachute slows a toy's fall best?
- Which plants make good acid–base indicators?
- What type of balloon rocket travels fastest?
- What is the best recipe for soap bubble mixture?
- Do tall people jump higher and further than shorter people?
- Does the amount of exercise you do affect your heart rate? In what way?
- What type of fabric keeps you warmest in winter?
- How do fertilisers affect the growth of plants?
- Does talking to plants improve their growth?
- Can plants grow without soil?
- What makes algae grow in an aquarium?
- What is the best shape for a boomerang?
- What type of wood gives off the most heat while burning?
- What makes iron rust?
- Which paint weathers best?
- Which battery lasts longest?
- Which type of glue is best?
- Which food wrap keeps food fresher?
- Which fabrics burn faster?
- How can the growth of mould on fruit be slowed down?
- Which concrete mixture is strongest?

Does talking to plants improve their growth?

1.4.2 The aim of the game

Each of the experiments you do to solve your problem should have an **aim**. The aim of the experiment is a statement outlining the purpose of the experiment. It is often more specific than the problem you are investigating and it should start with the word 'to'. Below are some examples of aims for experiments.

- To identify the flower pigment that makes the best acid–base indicator
- To determine whether the size of the sheet of paper used to make a paper aeroplane affects how far the plane will fly
- To compare the speed of balloon rockets gliding along different types of string
- To determine whether paper towel, cling wrap or aluminium foil is the best insulator of heat

1.4.3 Hypothesis or prediction?

A hypothesis is a sensible guess about how things work. It should be related to what you want to find out and can be tested with an experiment.

The results of the experiment may support the hypothesis. Scientists can't prove a hypothesis is 100% correct, but they can find evidence that supports it. They do many experiments to test a hypothesis, and sometimes different scientists test the same hypothesis in different ways. Even if all the experiments agree with the hypothesis, scientists still say it is supported by evidence, not proven.

A prediction is a specific guess about what will happen in the future or in an experiment. For example, if the sky is grey, you might predict it will rain soon. If you mix acid and magnesium, you might predict a gas will form. If you test your friends' heart rates, you might predict that James, the cross-country champion, will have the lowest heart rate.

FIGURE 1.4 A hypothesis, such as 'people who exercise regularly have a lower heart rate', can be tested.

A hypothesis is a general idea, like 'People who exercise regularly have lower resting heart rates than those who don't'. A prediction is more specific, like 'James will have a lower heart rate because he exercises a lot'.

KEY IDEA

- A problem is written as a question.
- An aim is more specific than a problem. It starts with the word 'to', then a verb.
- A hypothesis is a sensible guess about the outcome of an experiment. It should be able to be tested with an experiment.
- A prediction is a specific statement about what we think will happen in the future.

1.4.4 Use your observations

Your hypothesis and predictions should be based on observations you have made. They might also be based on your own reading. For example, if you are trying to design the best parachute for a toy, you should read about parachutes before writing your hypothesis. You might find out that light, closely woven fabric that does not increase in weight too much when wet makes better parachutes than heavy fabric that soaks up a lot of water. When walking home in the rain, you might observe that your cotton T-shirt soaks up a lot of water and becomes heavy, whereas your nylon jacket does not soak up water. As a result, your hypothesis might be: 'Closely woven nylon is the most effective fabric to use for a parachute'.

Fine-tuning your hypothesis

A statement that cannot be tested with a scientific experiment is not a suitable hypothesis. The statement 'People born in January are more conscientious than others' is not a good hypothesis unless you can find a reliable way to measure conscientiousness. The statement 'People born in January work more hours than others' is a better hypothesis because the number of hours worked is something that can be measured.

'Aeroplanes made from cardboard fly better than those made from paper' is not a suitable hypothesis because 'fly better' has not been defined so cannot be tested scientifically. 'Fly better' could mean fly further, fly in a straighter line or stay in the air longer. A better hypothesis would be 'Aeroplanes made from cardboard fly further than those made from paper.'

1.4 Activities

learnon

1.4 Quick quiz on	1.4 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 6	4, 5, 7, 8	9, 10

Remember and understand

1. MC **Identify** the correct definition of the term 'prediction'.
   A. A question you test with an experiment
   B. A specific guess about what will happen in the future or in an experiment
   C. An observation you make during the experiment that may support the aim
   D. Research you undertake before commencing an experiment
2. **Identify** the missing words and complete the sentences.
   a. An aim always starts with the word ____________.
   b. A ______________ is usually worded as a question to answer.
   c. The results of an experiment can ______________ a hypothesis but they never ______________ that the hypothesis is correct.
   d. A ______________ is an educated guess about how things work.
   e. The ______________ of an experiment is the purpose of the experiment.
   f. A hypothesis can be ______________ by carrying out a scientific experiment.
   g. We can use a hypothesis to make ______________.
   h. A good hypothesis is based on______________ and often also on research.
3. **Identify** the missing words and complete the passage.

   A ___________ is an educated guess about the outcome of an experiment. It should relate to your __________ and be able to be tested with __________. The results of your investigation will either support or not support your_________. It is_________ to prove conclusively that a______ is correct.

Apply and analyse

4. MC A student has written the following hypothesis:

   If the temperature is increased, then substances dissolve faster.

   Identify which of the following statements is a prediction based on this hypothesis.
   A. Sugar dissolves faster at 60 °C than at 20 °C.
   B. Sugar dissolves more slowly at 60 °C than at 20 °C.
   C. More sugar will dissolve in hot water than in cold water.
   D. Sugar is more soluble than salt at 60 °C.

5. **State** whether each of the following statements is an aim, a hypothesis, an observation or a prediction.
   a. Mould grows fastest in warm and humid environments.
   b. No mould will grow on bread if it is stored in the fridge.
   c. To find out the temperature at which mould grows fastest.
   d. After 5 days, 50 per cent of the slice of bread stored at 35 °C was covered in mould.
   e. After 3 minutes, the temperature of the coffee in the ceramic cup had dropped from 80 °C to 63 °C.
   f. Ceramic is a better insulator than plastic.
   g. To find out whether ceramic is a better insulator than plastic.
   h. Coffee will cool down faster in the plastic cup than in the ceramic cup.
6. **Identify** whether each of the following statements is a suitable hypothesis. If not, **justify** your answer.
   a. White chocolate tastes better than dark chocolate.
   b. Washing powder X removes tomato sauce stains faster than washing powder Y.
   c. Plants grow faster under red light than under green light.
   d. Sagittarians are nicer people than Leos.
   e. Playing video games increases the muscle strength in your thumbs.
   f. Playing video games affects the development of social skills.
   g. Science teachers are more interesting people than English teachers.
   h. Science teachers perform better in IQ tests than English teachers.
7. Consider the following table.

Problem	Observation	Hypothesis
The television remote control doesn't work.	If I press the 'on' button on the remote control, the television doesn't come on.	If the batteries are flat, then the remote control will not work.
My hair is sometimes dry and frizzy.	My hair is driest soon after washing it with Mum's shampoo.	If I wash my hair with Mum's shampoo, my hair becomes dry.
No parrots come to our bird feeder.	There is bread in the bird feeder, and magpies and miner birds feed there.	If I feed birds bread, then parrots will not eat it.

   Describe how you could test each of the three hypotheses.
8. A student has noticed that the flowers at the front of his house are open in the afternoon, but closed at night. He has also noticed that the flowers are closed when it is raining. He suspects that light intensity might determine whether the flowers are open or closed.
   a. Write a hypothesis based on the student's observations.
   b. Write a prediction based on the student's observations.
9. A student would like to investigate whether students who exercise regularly sleep better than students who do very little exercise.

   Write a hypothesis for the investigation. Make sure you consider what is meant by regular exercise and sleeping well.

Evaluate and create

10. **Outline** an investigation you could do to test each of the three hypotheses from the table in question 7.

Answers and sample responses are available in your digital formats.

LESSON 1.5 Controlled, dependent and independent variables

LEARNING INTENTION

In this lesson you will identify controlled, dependent and independent variables.

1.5.1 What is the difference between controlled, dependent and independent variables?

In order to answer a question scientifically, a controlled investigation needs to be performed and this will involve variables. In a controlled investigation, every variable except the one being tested is held constant, which stops the results being affected by an uncontrolled factor. The variables held constant are called **controlled variables**. The variable that you are investigating is called the independent variable, and you choose to change it to observe its effect on the variable you are measuring. The variable that you are measuring is called the dependent variable. It is expected to change when the independent variable is changed.

What is the application of variables in science?

In many branches of science research, questions are asked, such as 'what is the best way of doing this?'; 'how can this be done faster or more efficiently?' or 'how can we cure this disease?'. In order to answer complicated questions, investigations must be carried out that are well thought out and planned so that the results can be trusted and repeated.

When creating scientific questions, developing aims and formulating hypotheses, it is vital to know which variables are which. Understanding variables ensures that a **fair test** is created and your questions, aims and hypotheses are specific and targeted.

1.5.2 How do you identify and use controlled, dependent and independent variables?

Aim

Which iceblock shape is most successful at reducing the temperature of the water?

Materials

- 2 thermometers or temperature probes
- 2 identical glasses or beakers
- iceblock trays that make cube-shaped iceblocks
- iceblock trays that make spherical-shaped iceblocks
- 1 L of water
- measuring cylinder

Method

Step 1

Determine which variable you are changing and testing in your investigation; this is the independent variable. In this investigation, the aim is to investigate which iceblock's shape is most successful at reducing the temperature of the water.

Therefore, the independent variable is the shape of the iceblocks.

Step 2

Determine which variable you are measuring in your investigation. In this case, it is the temperature of the water.

Step 3

Ensure a fair test is created by making sure that only one variable can change and all other variables are controlled. Consider all the factors that need to be controlled: the amount of water, the volume of the iceblock, the initial temperature of the water, the number of iceblocks and the time.

Step 4

Conduct the investigation.

Determine the volume of water needed to fill the spherical iceblock tray by filling it using the measuring cylinder and recording the volume.

Using the measuring cylinder, fill the cube-shaped iceblock tray with the same volume of water as used to fill the spherical iceblock tray. Freeze both trays overnight for the same amount of time.

Step 5

Fill each glass to half its volume with water using the measuring cylinder to ensure each glass has the same volume in it. Add the thermometer or temperature probe to each glass. At the same time, add two spherical iceblocks to one glass but ensure it does not overflow, and add the same number of cube iceblocks to the other glass, ensuring that the water does not overflow.

Step 6

Measure and record the temperature in each glass until it stops falling and starts to rise. Repeat the experiment using the remaining iceblocks.

1.5 Activities

learnon

1.5 Quick quiz on	1.5 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3	–	–

1. For the investigation in section 1.5.2, looking at which iceblock shape is most successful at reducing the temperature of water:
   a. **identify** the independent variable
   b. **identify** the dependent variable
   c. **identify** three controlled variables.
2. The investigation in section 1.5.2 can be used to determine which iceblock cools a drink to the lowest temperature.
   a. **Describe** how this could be done.
   b. **Name** the dependent variable in this case.
3. To investigate various ways of keeping cut flowers alive, several different substances were added to the water in three identical vases. The substances were 5 g of sugar, 5 g of salt and 5 g of vinegar. A fourth vase was set up using only water with nothing added. A bunch of flowers was divided up so that there were the same number of individual flowers in each of the four vases.
   a. **Identify** the independent variable.
   b. **Identify** the dependent variable.
   c. **Name** the two controlled variables.
   d. **Explain** why one vase was set up with only water in it.

Answers and sample responses are available in your digital formats.

LESSON 1.6 Writing an aim and forming a hypothesis

LEARNING INTENTION

In this lesson you will learn how to write aims and hypotheses.

1.6.1 Why do we need to write an aim and form a hypothesis?

In science, we conduct investigations to gather data and results and draw conclusions. Every investigation requires an aim — a short statement of what we are trying to achieve. Alongside an aim, the ability to formulate predictions is important in science. This is done through the use of a hypothesis. Being able to write aims and hypotheses is a vital skill for any scientist.

What is the application of an aim and a hypothesis in science?

A hypothesis is an idea that is based on observation, which can be tested in an investigation by experiment or data. Investigations can involve testing, field work, using models or simulations, finding and using information for various sources and conducting surveys.

The aim is a statement about the direction of the scientific investigation. It provides a purpose of the investigation. A hypothesis is an educated prediction of the outcome of an investigation, which can be supported or unsupported through the results of an investigation.

A hypothesis is an educated prediction of the outcome of an investigation, which can be supported or unsupported through the results of an investigation.

1.6.2 How do we write an aim and form a hypothesis?

The following is an idea for an investigation, based on an area of interest. The purpose of the investigation is to find out whether the bushfood warrigal greens grows best from seeds or cuttings.

Materials

- warrigal greens seeds
- warrigal greens cuttings
- potting mix
- pots

Method

Step 1

To write an aim, you need to first identify your independent and dependent variables. The independent variable is what you are changing: Using seeds or cuttings from warrigal greens.

The dependent variable is what you are examining: The growth of warrigal greens.

Step 2

It often helps to write your idea as a scientific question; for example, how are warrigal greens best grown?

Step 3

Use this to develop your aim. An aim is usually written in one of two formats:

a. to investigate the effect of a change in the independent variable on the dependent variable
b. to investigate how the dependent variable is affected by a change in the independent variable.

For this investigation, some example aims might be:

- to compare the difference between the use of seeds and cuttings on the growth of warrigal greens
- to observe whether the growth of warrigal greens is affected by the use of seeds or cuttings during planting
- to determine whether warrigal green seeds or warrigal green cuttings result in the greatest amount of plant growth.

Step 4

Refine your aim into a hypothesis, in this case written as an 'if' and 'then' statement. This should again link your variables. For example, *if* the same number of warrigal seeds and cuttings are planted and the two crops compared after one month, *then* the cuttings will produce a greater weight of picked leaves.

Step 5

Check that your hypothesis is able to be tested or backed up by data. In this case, the two crops of leaves can be weighed and compared.

1.6 Activities

learnon

1.6 Quick quiz	1.6 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3	–	–

1. **Identify** whether the following statements are true or false.
   a. The aim of an investigation starts with an idea or problem.
   b. The aim is written as an if–then statement.
   c. The hypothesis is written as a question.
   d. The hypothesis must be able to be tested by experiment results or data.
2. A student was interested in investigating how to grow the bushfood warrigal greens, using seeds, to produce a plentiful crop in the shortest amount of time. The student observed that some plant seeds germinate only when soaked in water or exposed to smoke.
   a. Write an aim for the student's investigation.
   b. From your aim, write a hypothesis for an investigation.
   c. **Describe** how your hypothesis could be tested.
3. a. **Identify** whether each of the options below is written as an aim, a hypothesis or neither.
      i. To determine how much rubbish is collected from my school in one day.
      ii. If the different colours of new cars purchased this year were calculated, then the most popular colour would be black.
      iii. Chocolate is the most popular snack food at my school.
      iv. If the temperature drops below five degrees Celsius for three days in a row then it will rain on the fourth day.
      v. To investigate how tall a wall mirror should be in order for me to see my full height (185 cm) from one metre away.
   b. For any of the options in part a. that is neither an aim nor a hypothesis, rewrite it as a possible hypothesis.

Answers and sample responses are available in your digital formats.

LESSON 1.7 Planning investigations

LEARNING INTENTION

In this lesson you will plan an experiment or investigation.

1.7.1 Experiments

Experiments must be carefully planned to ensure that the results are valid, reliable, precise and accurate. Designing a scientific investigation usually begins by considering the variables involved in the experiment. You should also think about the observations and measurements that you will need to make. Most importantly, your experiment must be safe and minimise risk to yourself and others.

Variables

Variables are the quantities or conditions that can be changed in an experiment. There are different types of variables in experiments as shown below.

TABLE 1.2 Idea or problem: Do black cars heat up in the sun faster than white cars?

Type of variable	Definition	Example
Independent	The variable that is deliberately changed in the experiment	Colour of car
Dependent	The variable that is measured in the experiment	Temperature
Controlled	Variable that must be kept constant to ensure that the experiment is fair	• Location of car (both cars in full sun) • Outside temperature • Type of car • Window tinting • Location of thermometer in car

FIGURE 1.5 Which car will heat up faster on a hot day?

1.7.2 Valid experiments

A valid experiment tests what it is designed to test. For example, if you want to measure a student's intelligence, getting the student to complete an IQ test would be a more valid test of their intelligence than measuring how high they can jump.

An important feature of a valid experiment is to change only the independent variable. The independent variable is the condition that is being tested. In the example above, the independent variable is the colour of the car. The other variables should be controlled (kept the same) as far as possible.

In many instances, a **control** is needed for an experiment to be valid. A control group is identical to the test group(s) except that the independent variable is not applied. This allows scientists to compare the results with those of the test group, to see if the changes made by changing the independent variable actually have an effect. For example, if you want to test whether a fertiliser makes a plant grow faster, you would need to grow two plants under identical conditions and apply the fertiliser to only one of the plants. By comparing how quickly both plants grew, you could decide whether the fertiliser has an effect.

FIGURE 1.6 Does fertiliser make plants grow faster?

SCIENCE AS A HUMAN ENDEAVOUR: Developing mRNA vaccines

The development of mRNA vaccines, such as those used for COVID-19, showcases the importance of valid scientific experimentation. To test whether these vaccines were effective, researchers designed carefully controlled experiments during clinical trials.

In these trials, the independent variable was whether participants received the vaccine or a placebo (a control substance with no active ingredients). Other variables, such as age, health conditions and exposure to the virus, were carefully controlled to ensure that the observed outcomes were directly linked to the vaccine.

The inclusion of a control group was critical to the validity of these experiments. By comparing infection rates and immune responses between vaccinated and unvaccinated participants, scientists could determine whether the vaccine was effective. The results showed a significant reduction in severe disease and hospitalisation among vaccinated individuals, leading to the widespread adoption of this technology.

This example highlights how valid experiments, with well-defined independent variables and appropriate controls, play a pivotal role in advancing science and addressing global challenges. The success of mRNA vaccines also demonstrates how the principles of experimental design are applied in real-world scientific endeavours.

1. In the mRNA vaccine trials, what was the independent variable, and why was it important to include a control group?
2. How did scientists ensure that the trials tested what they were designed to test?
3. Why is it important to control variables like age and health conditions in vaccine trials?
4. What could happen if variables were not controlled properly during the trials?
5. How did the results of the vaccine trials provide evidence to support changes in public health policies?
6. Why is it important for scientific models and theories to adapt when new evidence, such as the results of clinical trials, becomes available?

Scientific knowledge, including models and theories, can change because of new evidence (VC2S8H01)

1.7.3 Keep it safe

The most important thing to consider when planning an investigation is safety. Your teacher may ask you to write a risk assessment before you start your investigation. This involves listing any potential hazards relating to your investigation and explaining how you will minimise these risks. For example, if you were doing an experiment to test whether the temperature of an acid affects how quickly it reacts with magnesium, your risk assessment might look like that in table 1.3.

FIGURE 1.7 Safety goggles are needed for some investigations to protect the eyes

TABLE 1.3 Minimising risk

Risk	How the risk will be minimised
Acid splashing into eyes	• Wear **safety goggles**, which form a seal against the face and are better protection than **safety glasses** when handling acid. • Heat acid using a water bath rather than directly over a Bunsen burner flame. • Use dilute acid rather than concentrated acid.
Cutting fingers when tearing small pieces of magnesium	• Use scissors to cut magnesium.

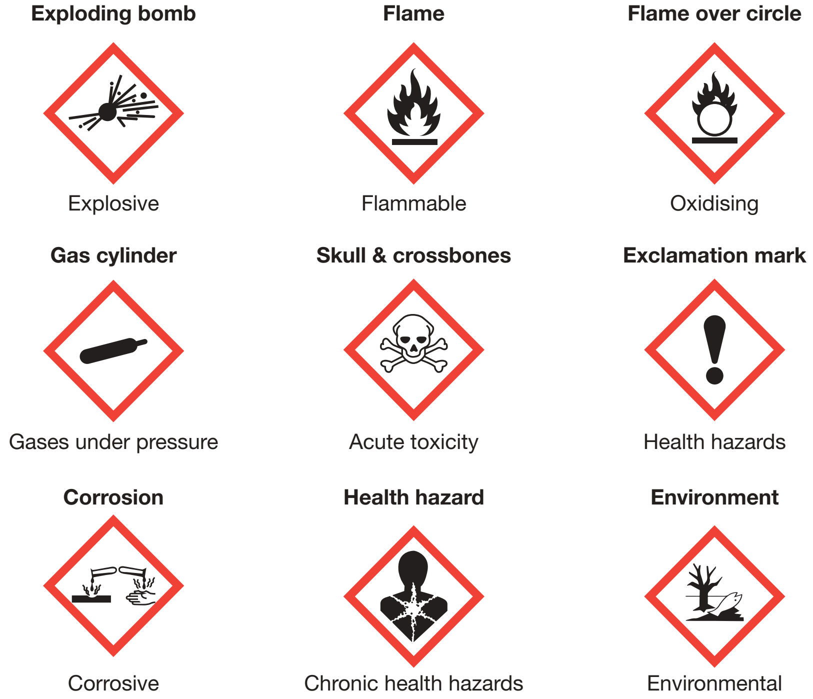
Hazardous substances

Hazardous substances are chemicals that can cause harm. Some have immediate effects, such as concentrated sulfuric acid, which burns the skin and causes blisters. Others may seem harmless at first, but long-term exposure can affect health.

Before using any chemical, it is important to understand the risks.

The symbols in figure 1.8 are part of the Globally Harmonised System (GHS) for labelling chemicals. These pictograms are internationally recognised and show the type of danger a chemical may pose. All hazardous substances must have clear labels with the right symbols.

FIGURE 1.8 The GHS pictograms



1.7.4 Keep it ethical

Ethics in science involves making decisions that are fair, responsible and respectful of people, animals and the environment. Scientists follow ethical guidelines to ensure investigations are conducted safely and fairly.

Some ethical values are universal, meaning most people worldwide agree on them. For example, protecting human rights and treating animals with care are widely accepted principles. However, other ethical values differ between individuals, cultures or societies. This can create challenges in science, as what is acceptable to some may be concerning to others.

When planning a science investigation, researchers must consider:
- *Safety* — ensuring experiments do not harm people, animals or the environment
- *Fairness* — conducting investigations honestly and without bias
- *Respect* — acknowledging different perspectives, especially when working with living organisms or historical sites
- *Consent* — making sure people involved in a study understand and agree to participate.

For example, scientists studying animal behaviour must ensure their research does not interfere with the animals' natural habitat or cause them distress. Similarly, medical experiments must follow ethical guidelines to protect the health and rights of participants.

Science helps solve real-world problems, but ethical decision-making ensures discoveries are responsible and respectful.

1.7.5 Surveys

Some experiments involve gathering data using a survey. Features of good surveys include:

- a large sample size. Many people should complete the survey.
- choosing your subjects carefully. If you carried out a survey to determine whether school students have a better awareness of the health effects of smoking than their parents, you would need to ensure that you surveyed both school students and parents. The survey would not be fair if you only surveyed males for the two age groups.
- keeping the questions short and easy to understand
- using an online survey to make collation of the results easier.

FIGURE 1.9 Electronic online surveys can be used to collect huge amounts of data.

1.7 Activities

learnon

1.7 Quick quiz on	1.7 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 4	5, 6, 7, 8	9, 10, 11

Remember and understand

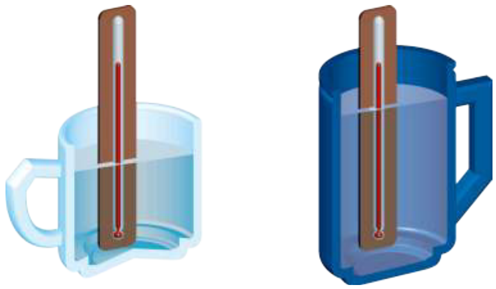
1. **Identify** the correct option for each of the following.
   a. The *controlled / dependent* variables must be kept constant in an experiment.
   b. A *valid / reliable* experiment measures what it is supposed to test.
   c. The *dependent / independent* variable is deliberately changed in an experiment.
   d. A list of the hazards in an experiment and how these will be minimised is called a *trial / risk assessment*.
   e. Something that can be changed in an experiment is known as a *control / variable*.
   f. The *dependent / independent* variable is measured in an experiment.
2. An experiment is done to find out whether cups made out of ceramic are better at keeping coffee warm than those made of Styrofoam. **Identify** whether each of the following is an independent, a dependent or a controlled variable.
   a. Volume of coffee in cup
   b. Length of time over which temperature is measured
   c. Shape of cup
   d. Material from which cup is made
   e. Temperature of coffee
3. A class conducts an experiment to find out what type of ball bounces the highest after being dropped to the ground from a height.

   Identify the independent, dependent and controlled variables in the experiment.
   a. Newness of the ball
   b. Method used to drop the ball
   c. Type of ball used
   d. Type of surface ball is dropped onto
   e. Technique used to measure height of bounce
   f. Height of the bounce
   g. Height from which ball is dropped

4. **Identify** some variables that might affect:
   a. how quickly a pot plant grows
   b. the cost of an overseas airfare
   c. the time it takes you to travel to school in the morning.

Apply and analyse

5. Amy and Saxon are trying to find out whether stoneware or glass cups are better for keeping water hot. The figure shows their experiment in progress.
   a. **State** at least two weaknesses in their experiment design.
   b. **List** all the variables that could affect the results of Amy and Saxon's experiment.
   c. **List** any variables that Amy and Saxon do not need to control.



6. Advertisements for washing powders and liquids often claim that they are more effective than others. Imagine that you are conducting an experiment to test a range of washing powders and liquids.
   a. **Outline** a method for your experiment.
   b. **List** the variables you will need to control.
   c. MC Identify the variable you will change.
      A. Mass of washing powder/liquid
      B. Duration of wash time
      C. Temperature of water
      D. Type of washing powder/liquid used
   d. **Explain** how you will compare the results of your tests.
7. Charlotte wanted to compare the amount of air in two brands of ice-cream. She placed a large spoon of each ice-cream in two different cups and let the ice-cream melt. She then measured how much liquid was in each cup. There was less liquid in cup B so she concluded that ice-cream B must contain more air.
   Describe one way in which Charlotte could improve the validity of her experiment.
8. Luca wanted to find out whether the mass of a rock affects how far the rock can be thrown. He weighed some rocks, threw each rock as far as possible and measured the distance by pacing between the point where she threw the rock and the point where it landed.
   a. **State** at least two risks associated with this experiment and how each risk could be minimised.
   b. **Describe** how the experiment could be made more valid.

Evaluate and create

9. **Construct** experiments to test the following hypotheses.
   a. Eggs become less dense as they age.
   b. Detergent A produces more foam than detergent B.
   c. Cola drink P contains more sugar than cola drink C.
   d. Talking to plants makes them grow faster.
   e. Chocolate S melts at a higher temperature than chocolate Q.
10. Design a survey to test the hypothesis that people born after 1995 are more likely to wear sunscreen and have better awareness of the health effects of overexposure to sunlight than those born before 1995.
11. a. The bounce height of a tennis ball is investigated in different conditions.
    Suggest how the bounce height of a tennis ball is affected (increases, decreases, varies) in the following conditions:
      i. When the ball is damp
      ii. When the ball is hot
      iii. As the ball gets old and worn
      iv. On different tennis court surfaces
    b. Design an investigation to answer one or more of these questions.

Answers and sample responses are available in your digital formats.

LESSON 1.8 Conducting investigations

LEARNING INTENTION

In this lesson you will learn how to conduct an investigation.

1.8.1 Working in groups

An investigative project is any type of scientific investigation where you have the opportunity to explore your interests and deepen your scientific understanding of a focus area. They may be completed individually or collaboratively. Working in groups has many advantages. You can divide up a task to get more work done in a short period of time. Each group member brings along their interests, expertise and skills and, if these are used effectively, the quality of the work produced will be increased. When doing practical work, each team member can have a different role so that the task can be carried out efficiently.

FIGURE 1.10 When working in a group, each team member brings along their expertise and skills.

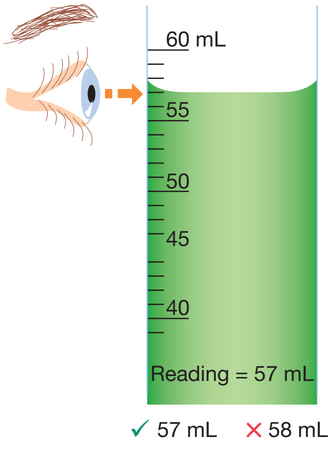
Group work can have some problems. People might get upset if the work is not shared fairly. Sometimes, group members have different ideas about how to do the project and argue. To avoid these issues, it's helpful to give each person a specific job at the beginning. Think about what each person is good at and assign roles based on that.

1.8.2 The right tool for the job

In lesson 1.2 we saw that scientific investigations involve making observations. We also saw that quantitative observations include measurements.

When collecting quantitative data, it is important to select the right tool for the job, and to use instruments correctly to ensure accurate and precise measurements. In lesson 1.2 we saw that our choice of equipment can affect the precision of our measurements. A tape measure measures distance more precisely than a trundle wheel, and a measuring cylinder measures volume more precisely than a **beaker**. If we use the equipment incorrectly, even the most precise measuring tool will not produce an accurate measurement. A measuring cylinder is designed to have the volume read from the bottom of the meniscus — the curved edge of the liquid. If the volume is read where the meniscus meets the sides of the measuring cylinder, the measurement is inaccurate.

FIGURE 1.11 Reading the volume of a liquid needs to be done carefully to avoid giving a false result.



Selecting the correct equipment can also affect the validity of an investigation. For instance, if you wanted to measure the length of your desk, a thermometer would not be the correct tool for the job. This is an obvious example, but sometimes there are measuring tools designed to measure similar things and one tool is best suited for a particular type of measurement. If you needed to measure the diameter of a carbon rod, you could use a ruler, but calipers, which are specifically designed for this type of measurement, would be a better choice in this instance.

FIGURE 1.12 Calipers are the appropriate tool to measure the diameter of a carbon rod.

SCIENCE AS A HUMAN ENDEAVOUR: Observing Black Holes Using the Event Horizon Telescope

In 2019, scientists released the first-ever image of a black hole. This historic achievement was made possible through the collaboration of over 200 researchers from multiple disciplines as part of the Event Horizon Telescope (EHT) project. The image showed the supermassive black hole at the centre of the galaxy M87, approximately 55 million light-years away.

This groundbreaking observation relied on the use of advanced tools and techniques to collect and process quantitative data. The EHT network combined radio telescopes across the globe, creating a virtual telescope the size of Earth. This level of precision was essential for capturing the faint signals from the black hole's event horizon, where light cannot escape due to the intense gravitational pull.

The success of this project highlights how multidisciplinary collaboration and the correct selection and use of scientific instruments can lead to profound discoveries. Physicists, computer scientists, engineers and astronomers worked together, each contributing their unique perspectives and expertise. The results have advanced our understanding of black holes, validated predictions of Einstein's theory of general relativity and inspired new research into the nature of the universe.

1. Why did scientists need to combine radio telescopes from around the world to observe the black hole in M87?
2. What was significant about capturing the first image of a black hole? How did this contribute to our understanding of physics?
3. What roles did different types of scientists (e.g. astronomers, computer scientists, engineers) play in the success of the EHT project?
4. Why is it important for researchers from different disciplines to collaborate on complex scientific problems?
5. How might the techniques used in the EHT project be applied to other areas of science or technology?
6. What challenges do you think the researchers faced when processing and interpreting the data collected by the EHT? How might they have overcome these challenges?

Multidisciplinary endeavours to advance scientific knowledge make use of people's different perspectives and worldviews (VC2S8H02)

1.8.3 Using the correct units

When recording measurements, it is important to include units. Measurements are meaningless without units. If your teacher told you that the mass of an object was 5, is it 5 mg, 5 g or 5 kg?

The International System of Units (SI units) consists of a set of units that have been agreed upon worldwide. These are the units that should be used when reporting on scientific investigations.

TABLE 1.4 Common units of measurement and how they are measured

Measurement	Instruments used	SI unit	Other units
Length	Ruler, trundle wheel, tape measure	Metre (m)	Inch, foot, mile
Mass	Scales	Gram (g)	Pound, stone, ounce
Temperature	Thermometer	Degree Celsius (°C)	Degree Fahrenheit (°F)
Volume	Measuring cylinder, pipette	Litre (L), cubic metre (m^3)	Cup, gallon

The International System of Units includes a set of prefixes as shown in table 1.5.

TABLE 1.5 Common prefixes used in measurement terms

Prefix	Abbreviation	Meaning
Nano	n	0.000 000 001
Micro	μ	0.000 001
Milli	m	0.001
Centi	c	0.01
Deci	d	0.1
Deca	da	10
Hecto	h	100
Kilo	k	1000
Mega	M	1000 000
Giga	G	1000 000 000
Tera	T	1000 000 000 000

SAMPLE PROBLEM 1 Converting units

How many cm in 3.2 km?

To convert 3.2 km to cm, we need to convert the units:

$$\begin{aligned} 1 \text{ km} &= 1000 \text{ m, so} \\ 3.2 \text{ km} &= 3.2 \times 1000 \text{ m} \\ &= 3200 \text{ m} \end{aligned}$$

1 cm = 0.01 m, so in 1 m there are 1/0.01 = 100 cm

$$\begin{aligned} \text{Thus } 3200 \text{ m} &= 3200 \times 100 \\ &= 32\,000 \text{ cm} \end{aligned}$$

THINK	WRITE
1. To convert 3.2 km to cm, we need to convert the units: 1 km = 100 m	Therefore $3.2 \text{ km} = 3.2 \times 1000 \text{ m} = 32\,000 \text{ m}$
2. 1 cm = 0.01 m	Therefore in 1 m there are $1/0.01 = 100 \text{ cm} = 32\,000 \text{ cm}$

ACTIVITY: Converting units

1. A room has a length of 4.5 m. Convert this length to cm.
2. A dog weighs 5.325 kg. Convert the dog's mass to grams.
3. The lines on a grid are 2 mm apart. How many cm apart are they?
4. A red blood cell has a diameter of 6.9 μm. Convert this diameter to cm.
5. The average person in Australia uses 274 L of water per day. How much water does the average Australian use in a year? Give your answer in litres and megalitres.

INVESTIGATION 1.2

The balloon rocket

In this investigation, you will be practising many of the skills in this lesson, including working in a team and selecting the most appropriate measuring equipment.

Aim

Write your own aim, after you have decided what your independent and dependent variables will be. Complete the aim in this format: To investigate the effect of (independent variable) on (dependent variable).

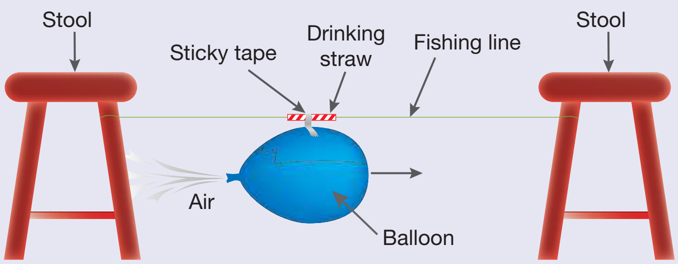
Materials

- 2 stools or chairs
- straw
- sticky tape
- fishing line
- balloon
- stopwatch
- different types of string

Method

1. Thread the fishing line through the straw and tie the ends around the legs of two stools or chairs as shown below.
2. Blow up the balloon and, while holding it closed, use a piece of sticky tape to attach the balloon to the bottom of the straw.

Which variables affect the speed of the balloon rocket?



There are many variables that can affect how far and how fast the balloon rocket travels. Your group will need to choose one of these variables and design an investigation to test the effect of this variable on either the speed of the rocket or the distance it travels. When designing your investigation, think about the following:

1. What is your independent variable (the thing you are changing)? In your method, you need to clearly state how you are changing this variable.
2. What is your dependent variable? Which piece of equipment and which units will you use to measure this?
3. Can you include multiple trials?

Results

Record your results in a table. Your table should be in the following format.

Independent variable (units)	Dependent variable (units)			
	Trial 1	Trial 2	Trial 3	Average

Discussion

1. To make the experiment fair, only one variable should be changed. All other variables should be controlled (kept the same). Complete the table below. The first line has been completed for you.

Variable	How this variable was controlled
Amount of air in balloon	We blew up the balloon to the same size each time.

2. Describe two possible changes to this investigation that would address validity or accuracy.

Conclusion

Write a conclusion for this investigation. It should address the aim that you wrote.

1.8 Activities

learnon

1.8 Quick quiz on	1.8 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 3, 5, 6	2, 4, 7, 10	8, 9

Remember and understand

1. MC When working in a group, resentment can build up if the work is not divided up fairly. **Identify** one way to avoid this.
   A. Assign each group member a role at the start of the project.
   B. Assign a group leader, who should do all the work.
   C. Ask the teacher to make the lazy students do their work.
   D. This is unavoidable, so the students who did all the work should get full marks and the students who did hardly any work should get zero marks.
2. **Name** an item of equipment you would use to measure:
   a. the temperature of hot water
   b. the mass of a small beaker of water
   c. the volume of a small quantity of water.
3. MC **Identify** which of the following is a SI unit.
   A. Pound
   B. Gallon
   C. Metre
   D. Mile
4. **Explain** what SI units are. Give some examples.

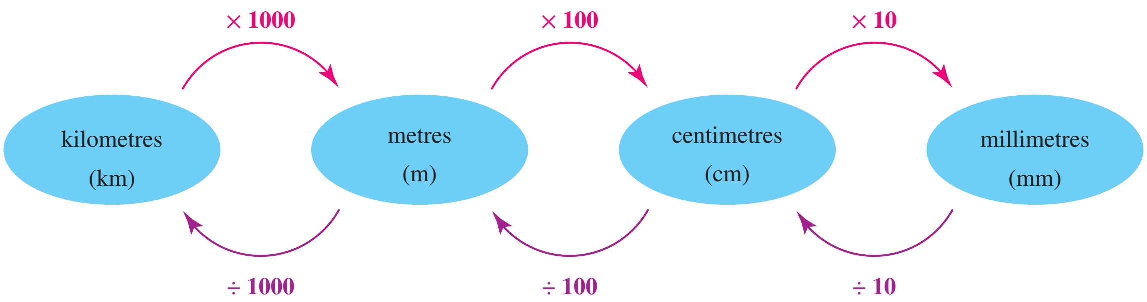
Apply and analyse

5. **MC** A student is using a measuring cylinder incorrectly. Instead of reading the volume from the bottom of the meniscus, they consistently read the volume where the edge of the meniscus meets the sides of the measuring cylinder.

   Their measurements will be:
   A. inaccurate and greater than the actual measurement.
   B. inaccurate and less than the actual measurement.
   C. accurate but not precise.
   D. accurate but not valid.
6. **MC** If you needed to measure 36 mL of water, **identify** the piece of equipment that would provide the most accurate measurement?
   A. A 250-L beaker with graduation lines that are 50 mL apart
   B. A 50-mL beaker with graduation lines that are 10 mL apart
   C. A 100-mL cylinder with graduation lines that are 1 mL apart
   D. A 50-mL measuring cylinder with graduation lines that are 0.5 mL apart
7. A student is looking at a hair under a microscope. They have used a special grid to work out that the hair is 25 micrometres thick. Convert this measurement to millimetres.

Evaluate and create

8. The figure below shows how to convert units of length. Create a similar figure for units of mass.



9. **Evaluate** the benefits of using SI units in scientific investigations.
10. A student wanted to find out if a ceramic mug would keep a drink hot longer than a plastic cup. She filled the mug and the cup with hot water from the kettle. After a while, she placed her finger in the water in each cup to find out which one felt warmer.

    Explain how using the correct equipment could greatly improve the validity of this investigation.

Answers and sample responses are available in your digital formats.

LESSON 1.9 Organising data

LEARNING INTENTION

In this lesson you will learn how to organise data into tables and graphs.

1.9.1 Tables

Values or measurements obtained from an investigation are called data. Having collected the data, it is important to present it clearly so that another person reading or studying the information can understand it. Tables and graphs are a great way to organise data.

A table organises data so that trends are more easily identified. An example of a simple table is shown in figure 1.13. It includes all the features you need to remember when constructing a table.

FIGURE 1.13 An example of a simple table

Always include a title for your table.

The column headings show clearly what has been measured. Include the measurement units in the headings.

The independent variable is usually on the left.

Temperature of Earth at different depths

Depth (km)	Temperature (°C)
0	15
1	44
2	73
3	102
4	130
5	158
6	187
7	215
8	242

The dependent variable is usually on the right.

Use a ruler to draw lines for rows, columns and borders.

Enter the data in the body of the table. Do not include units in this part of the table.

You may need to construct a more complex table, like table 1.6, when carrying out multiple trials in an experiment.

TABLE 1.6 Do large paper aeroplanes fly further than smaller planes?

Size of paper used to make paper plane (cm)	Distance flown (m)			
	Trial 1	Trial 2	Trial 3	Mean
14 × 21	4.5	4.9	4.6	
10 × 15	7.2	5.9	5.8	
6 × 9	3.4	3.6	3.5	

FIGURE 1.14 How far can this paper aeroplane fly?

1.9.2 Is the data reliable?

Once the data has been organised in a table, it is easier to compare the results and assess the reliability of the data. Data is considered reliable when multiple trials have been carried out and the results are consistent. Data points that are very different from the other results are called outliers and they are not included when calculating the average.

1.9.3 Mean and range

Mean is another word for average. To calculate the mean of a set of numbers, use the formula:

$$\text{Mean} = \frac{\text{sum of value}}{\text{total number of values}}$$

For example, to calculate

Calculate the average of the following numbers, first calculate the sum: 15.3, 17.8, 16.1, 17.2

$$\begin{aligned}\text{Sum of numbers} &= 15.3 + 17.8 + 16.1 + 17.2\\ &= 66.4\end{aligned}$$

$$\begin{aligned}\text{There are 4 numbers, so: Mean} &= \frac{66.4}{4}\\ &= 16.6\end{aligned}$$

KEY IDEA

The range tells us if there is a lot of difference between the smallest and the largest value. In an experiment, when carrying out multiple trials, results are considered reliable when multiple trials have been carried out and the values obtained in the different trials are similar. The data has a small range. To calculate the range of a set of numbers, use the formula:

$$\text{Range} = \text{largest value} - \text{smallest value}$$

SAMPLE PROBLEM 2 Calculating range

Calculate the range of the following numbers: 15.3, 17.8, 16.1, 17.2

THINK	WRITE
The largest value is 17.8, and the smallest value is 15.3.	$\begin{aligned}\text{Range} &= 17.8 - 15.3\\ &= 2.5\end{aligned}$

ACTIVITY: Calculating mean and range

1. Calculate the mean and range for each set of numbers shown below.
   a. 34, 63, 45, 73, 54
   b. 2.3, 6.7, 4.3, 5.5, 2.5, 4.7
   c. 5.6, 5.7, 5.5, 5.6, 5.4, 5.8
   d. 1432, 5643, 7865, 5698, 3212, 9876, 9887
   e. 45.65, 34.23, 12.45, 54.43
2. a. Identify any outliers in table 1.6.
   b. Calculate the average distance flown by each plane.
   c. Write a conclusion for the experiment.

1.9.4 Using graphs

Why use graphs?

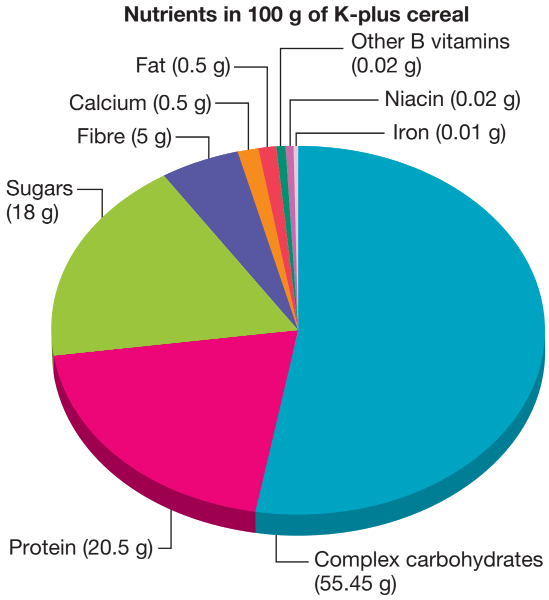
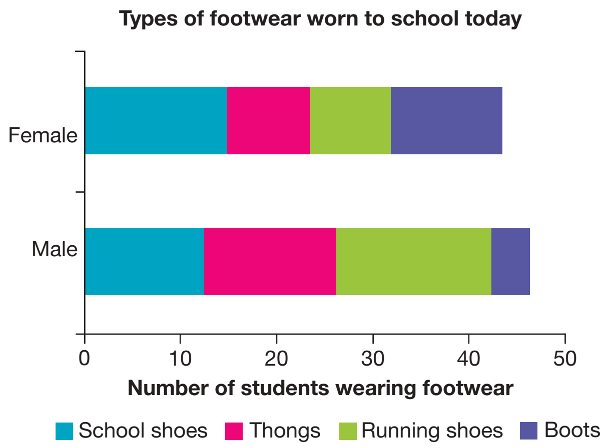
Organising data as a graph is a widely recognised way of making a clear presentation. It makes it easier to read and interpret the information, show trends and make conclusions.

Types of graphs

There are five different types of graphs:

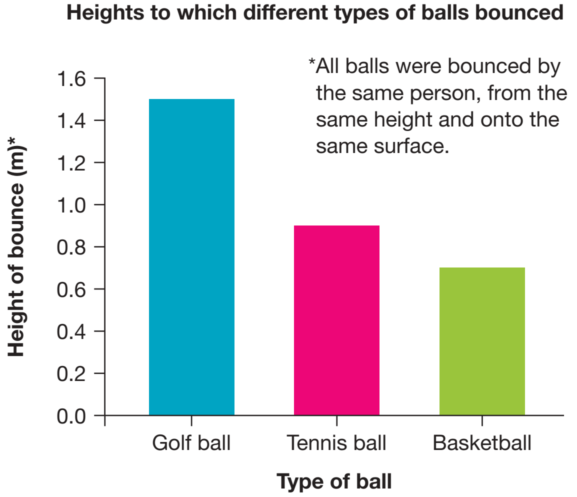
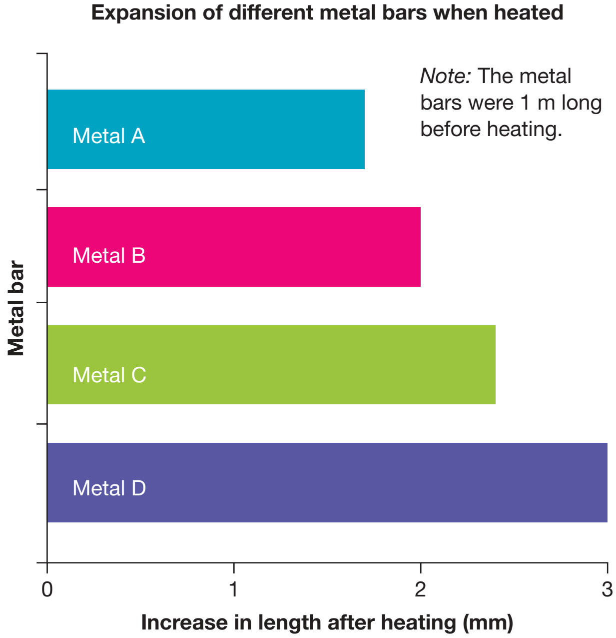
- pie charts
- column graphs and bar graphs
- divided bar graphs
- histograms
- line graphs.

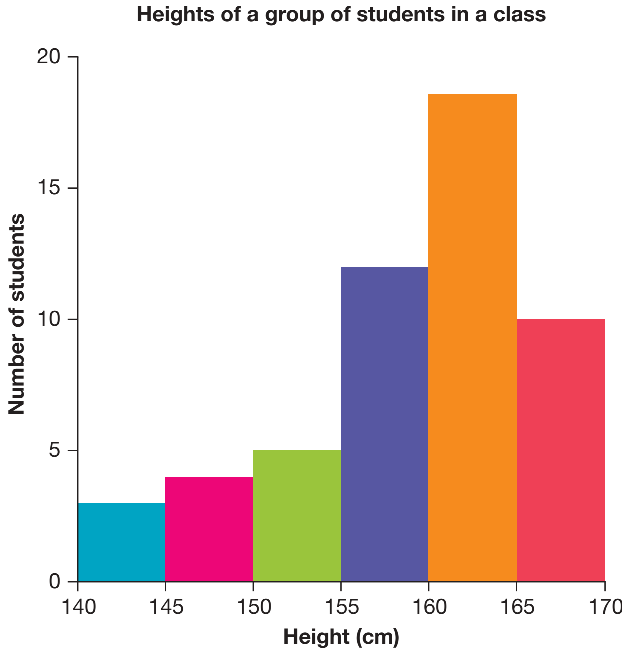
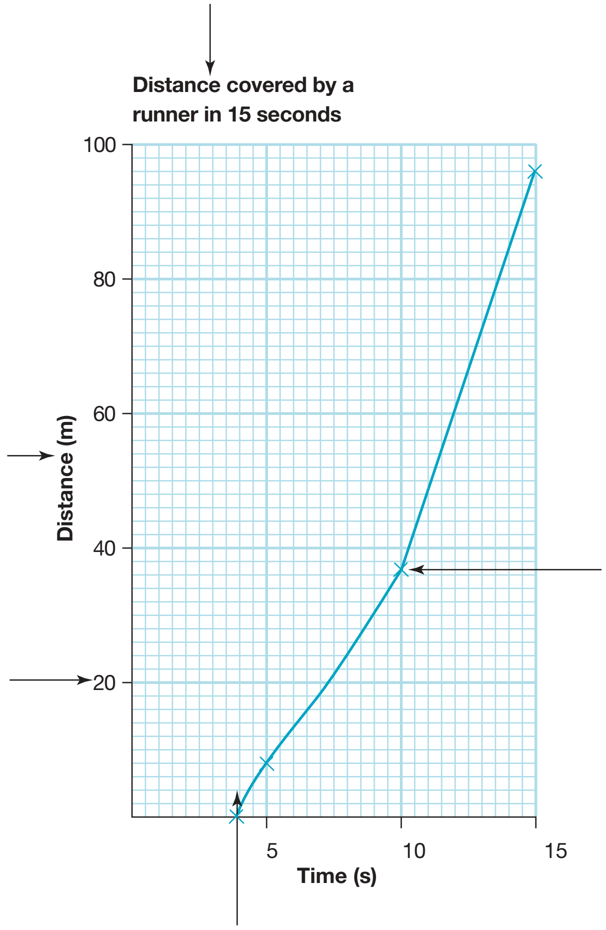
TABLE 1.7 Different types of graph and when you might use them

Type of graph	When to use
Pie chart 	This type of graph can be used when the data can be added as parts of a whole.
Divided bar graph 	Divided bar graphs are also used to represent parts of a whole. However, the data are represented as a long rectangle, rather than a circle, divided into sections.

(continued)

TABLE 1.7 Different types of graph and when you might use them *(continued)*

<table>
<tr><th>Type of graph</th><th>When to use</th></tr>
<tr><td>Column graph and bar graph

</td><td>Used to present data where the independent variable consists of categories. The categories can be words (e.g. type of ball) or numbers.
If the independent variable consists of numbers, it is non-continuous. That means that each number represents a category, rather than a value on a continuous scale.</td></tr>
</table>

Histogram (A histogram is similar to a column graph, but the columns touch.) 	Used to present data where the independent variable is a range.
Line graph 	Used to represent data where the independent variable consists of continuous numerical data.

KEY IDEA

Numerical data can be *continuous* or *discrete*.

- Continuous data can take on any value and there can be values between the numbers on the scale, including fractions and decimals. For instance, if you collected information about the foot length of the students in your class, the scale might include the numbers 27 and 28, but it is possible for students to have feet that have a length between these two numbers, such as 27.6 cm for instance.
- Data is discrete when the numbers represent categories. For instance, if you collected data about the number of pets students have, the scale would include the numbers 1, 2, 3 etc., but it is not possible for a student to have a number of pets between these values. You cannot have 2.5 pets.

1.9.5 Spreadsheets

A spreadsheet allows us to present data in columns and rows. Formulas can be used to carry out calculations and the data can be graphed and manipulated quickly and conveniently.

FIGURE 1.15 A spreadsheet is a useful tool to organise and analyse data.

E7 | fx | =AVERAGE(A7:D7)

	A	B	C	D	E
1		Height of seedlings (cm)			
2	Day	seedling 1	seedling 2	seedling 3	Average
3	1	5	4	6	4
4	2	6	4	6	4.5
5	3	7	5	8	5.75
6	4	7	5	9	6.25
7	5	8	6	10	7.25

INVESTIGATION 1.3

Dissolving aspirin

Aim

To investigate the effect of temperature on dissolving time

Materials

- beaker
- thermometer
- ice
- Bunsen burner, tripod, heatproof mat
- 2 effervescent tablets, such as Aspro Clear
- stopwatch

Method

1. Your teacher will assign each group two temperatures to test; for example, your teacher might ask you to test 20 °C and 50 °C.
2. Pour 200 mL of water into a beaker. Adjust the temperature of the water by adding ice or by heating the water over a Bunsen burner until the water temperature matches one of the temperatures you are to test.

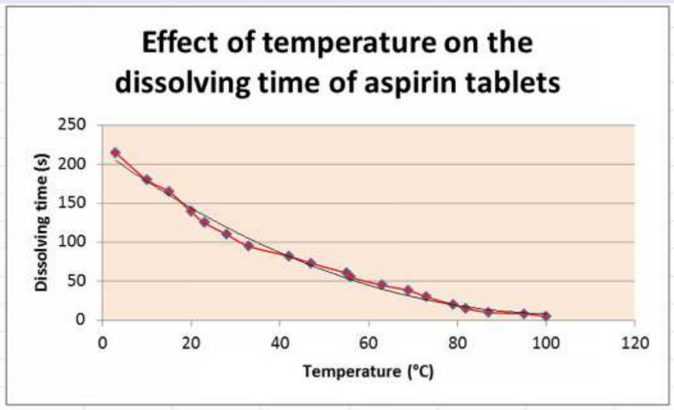
3. Add one of the tablets to the water. Use the stopwatch to record the time taken for the tablet to dissolve completely.
4. Repeat these two steps for the second temperature.

Results

1. Use the following instructions to plot your data using spreadsheet software.
   Note: The following instructions assume that you are using Excel. If you are using a different spreadsheet package, you may need to modify some of the steps accordingly.
2. Create a spreadsheet with the column headings 'Temperature (°C)' and 'Time taken to dissolve (s)'.
3. Enter all the groups' results in your spreadsheet.

	A	B
1	Temperature (°C)	Time taken to dissolve (s)
2	3	215
3	10	180
4	15	165
5	20	139
6	23	125
7	28	110
8	33	95
9	42	82
10	47	73
11	55	60
12	56	55
13	63	45
14	69	38
15	73	30
16	79	20
17	82	15
18	87	10
19	95	8
20	100	5

4. If necessary, put the results in order from the lowest to the highest temperature by selecting (highlighting) all the data and using the Sort function. You should end up with a table similar to the one shown.
5. With the data selected, click on the Insert tab, then on X Y (Scatter), and choose the option where the points are joined by a smooth line. A graph similar to the one shown should appear. You can then add axis labels and a title.



Discussion

1. Describe the trend in the data.
2. Does your data include any outliers? Do you think these should be included in the spreadsheet? Why?
3. In this experiment, what was/were:
   a. the independent variable
   b. the dependent variable
   c. the controlled variables (identify at least 3)?
4. Suggest two improvements that could be made to this investigation.

Conclusion

Write a conclusion for this investigation.

1.9 Activities

learnON

1.9 Quick quiz (on)	1.9 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3	4, 5, 7, 10	6, 8, 9, 11

Remember and understand

1. **Explain** the difference between a histogram and a bar chart.
2. MC **Identify** which of the following is *not* true about displaying data in a table.
   A. The table should have a heading.
   B. The dependent variable should be in the first column and the independent variable in the second column.
   C. The table should be easy to read.
   D. The table should include units in the column headings.
3. MC **Identify** the correct sentence ending. When organising data in a table:
   A. the independent variable is usually on the left.
   B. the independent variable is usually on the right.
   C. the controlled variable is usually on the left.
   D. the dependent variable is usually on the left.

Apply and analyse

4. **Calculate** the mean and range for the following sets of numbers. Give your answer to one decimal place if the answer is not a whole number.
   a. 25, 34, 21, 56, 72, 65, 59
   b. 45.4, 34.5, 26.2, 38.2, 37.6
5. **Construct** a column graph using the information in the table below.

Nutrients in 30-g serving of ice-cream

Nutrient	Amount (g)
Protein	2.00
Fat	6.00
Carbohydrate — polysaccharide	11.00
Carbohydrate — sugars	10.00
Cholesterol	0.02
Calcium	0.10
Potassium	0.80
Sodium	0.05

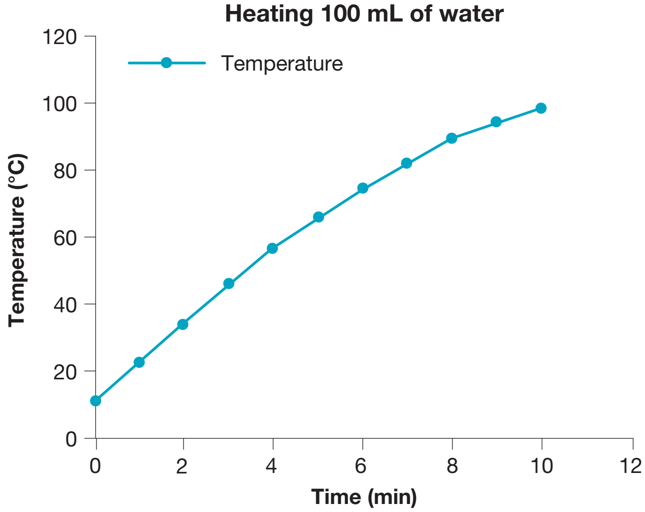
6. The following table shows information about the temperature of Earth at different depths.

Temperature of Earth at different depths

Depth (km)	Temperature (ºC)
0	15
1	44
2	73
3	102
4	130
5	158
6	187
7	215
8	242

a. **Construct** a line graph for the data shown in the table below.
b. Use your graph to **deduce** the temperature at a depth of:
   i. 4.5 km
   ii. 7.5 km.

7. Use the graph to answer the following questions.



a. **Identify** the length of time the experiment took.
b. **Identify** the temperature of the water when the experiment began.
c. **State** how long it took for the water to boil.
d. **State** how many readings were taken.
e. What would you expect the graph to look like after 10 minutes? **Explain** your answer.
f. How would you expect the graph to change if only 50 mL of water was heated? **Explain** your answer.
g. **Predict** the results for a 200-mL beaker of water. Perform the experiment to check your predictions.

8. Study the data in the following table.

Relationship between the speed of a car and its stopping distance

Speed of car (m/s)	Stopping distance (m)
0	0
10	12
20	36
30	72
40	120

a. **Construct** a graph of the data.
b. **Summarise** a conclusion about the information in the graph.
c. **Explain** how this information could be applied to your everyday life.

9. Study the data in the following table.

Uses of plastics in Australia

Use	Percentage
Agriculture	4.0
Building	24.0
Electrical/electronic	8.0
Furniture and bedding	8.0
Housewares	4.0
Marine, toys and leisure	2.0

(continued)

(continued)

Use	Percentage
Packaging and materials handling	31.0
Transport	5.0
Other	14.0

a. **Suggest** a suitable graph type and prepare a graph from this table.
b. Choose two uses of plastics from your graph. For each use, state a particular item that is made of plastic.
c. There has been recent controversy about the waste products that humans create.
  i. **Suggest** uses of plastics that would contribute to waste products. List them and **explain** your choices.
  ii. **Suggest** alternatives that could help to reduce the amount of plastic waste products.

Evaluate and create

10. **Discuss** two advantages and two disadvantages of using a computer spreadsheet program to store data rather than keeping handwritten records in a book.
11. The following table shows the percentage composition of salts present in seawater.

Salt composition of seawater

Salt	Percentage
Calcium carbonate	0.34
Calcium sulfate	3.60
Magnesium bromide	0.22
Magnesium chloride	10.90
Magnesium sulfate	4.70
Potassium sulfate	2.50
Sodium chloride	77.24
All others	0.50

Construct a pie chart based on the data in this table.

Answers and sample responses are available in your digital formats.

LESSON 1.10 Creating a simple column or bar graph

LEARNING INTENTION

In this lesson you will construct simple column and bar graphs.

1.10.1 What are column or bar graphs?

Column graphs and bar graphs show information or data in columns. In a bar graph, the bars are drawn horizontally, and in column graphs they are drawn vertically. They can be hand-drawn or constructed using computer spreadsheets.

How are column graphs useful?

Column graphs are useful for comparing quantities. They can help us understand and visualise data, see patterns and gain information. For example, we can use them to help understand rainfall patterns in different months (figure 1.16) or to help identify which subjects are favoured by students in a year 8 class (figure 1.17).

FIGURE 1.16 Rainfall at Darwin International Airport, Northern Territory

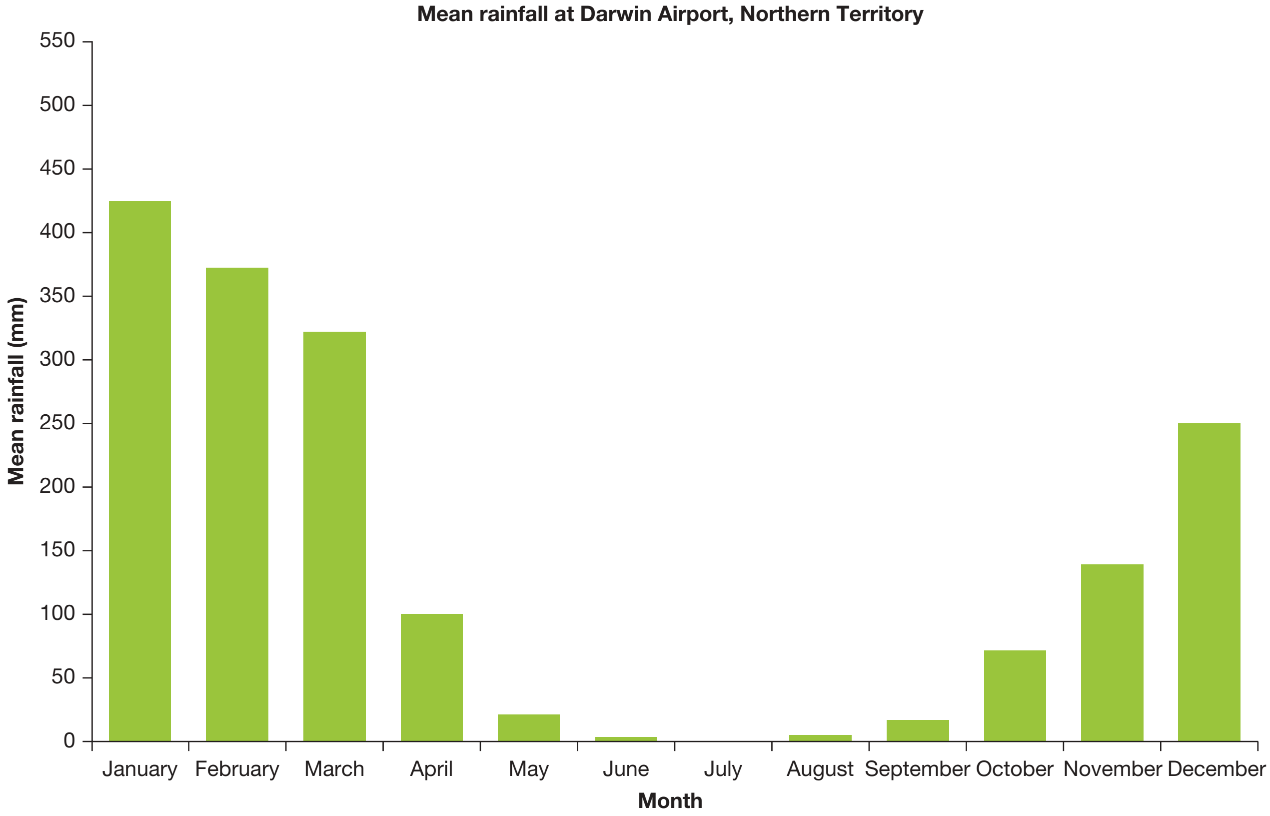
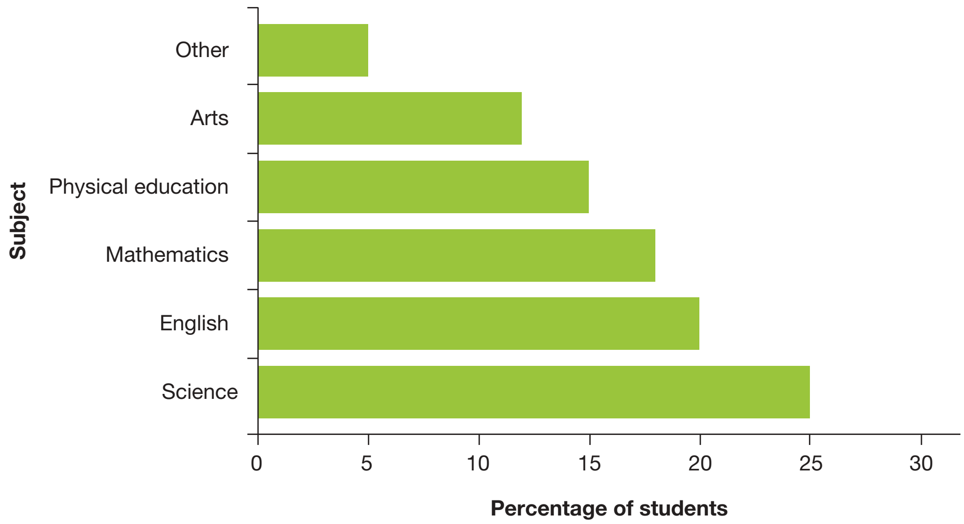


FIGURE 1.17 Favourite subjects in Class 8AB



A good column and bar graph have:

- ruled axes
- labelled axes
- a space between each column
- a title
- the source of information.

What is the application of column or bar graphs in science?

Column or bar graphs are useful to compare or investigate one or more numerical variables across different categories. There are different types of column or bar graphs including individual, clustered and stacked.

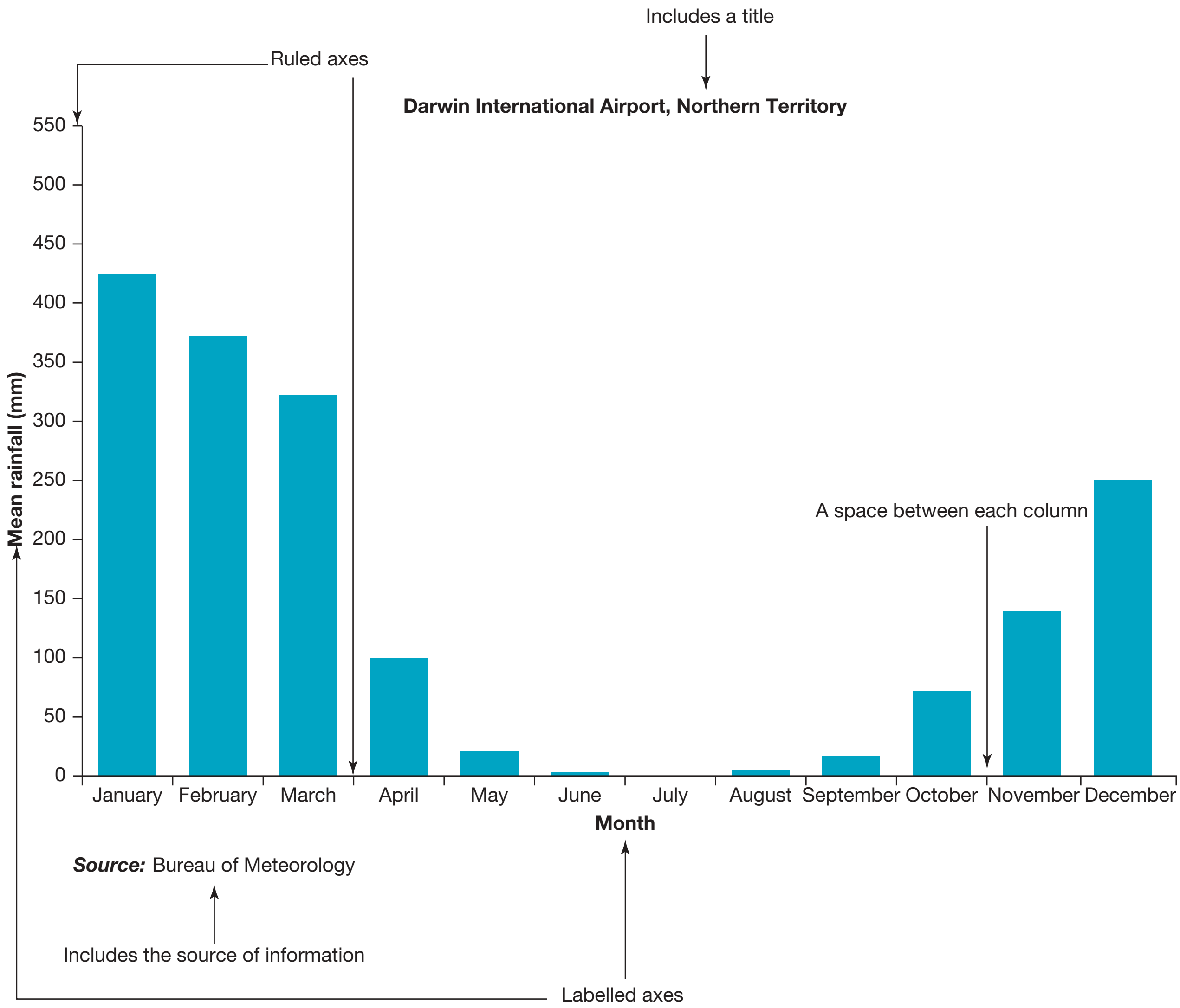
1.10.2 How to complete a column graph

Materials

- table of data
- graph paper
- pencil
- ruler

Model

FIGURE 1.18 A labelled column graph



Method

Step 1

Examine the data. Decide on the scale to use for your vertical axis. For this example, the vertical axis should start at zero and increase at intervals to suit the data. As the highest rainfall for any month for Cardwell is 465.9 mm, intervals of 50 would be suitable. For this exercise, you could use 1 cm to represent 50 mm of rainfall. Draw your vertical axis according to the scale you have devised.

TABLE 1.8 Mean monthly rainfall for the years 1871 to 2016, Cardwell, Queensland

Statistics	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean rainfall (mm) for years 1871 to 2016	438.5	465.9	400	208.6	94.7	47	32.4	29.2	38.5	54.4	115.2	193.5

Source: © Bureau of Meteorology

Step 2

Decide on the width and spacing of the columns and draw your horizontal axis to fit. Ensure that each column is the same width.

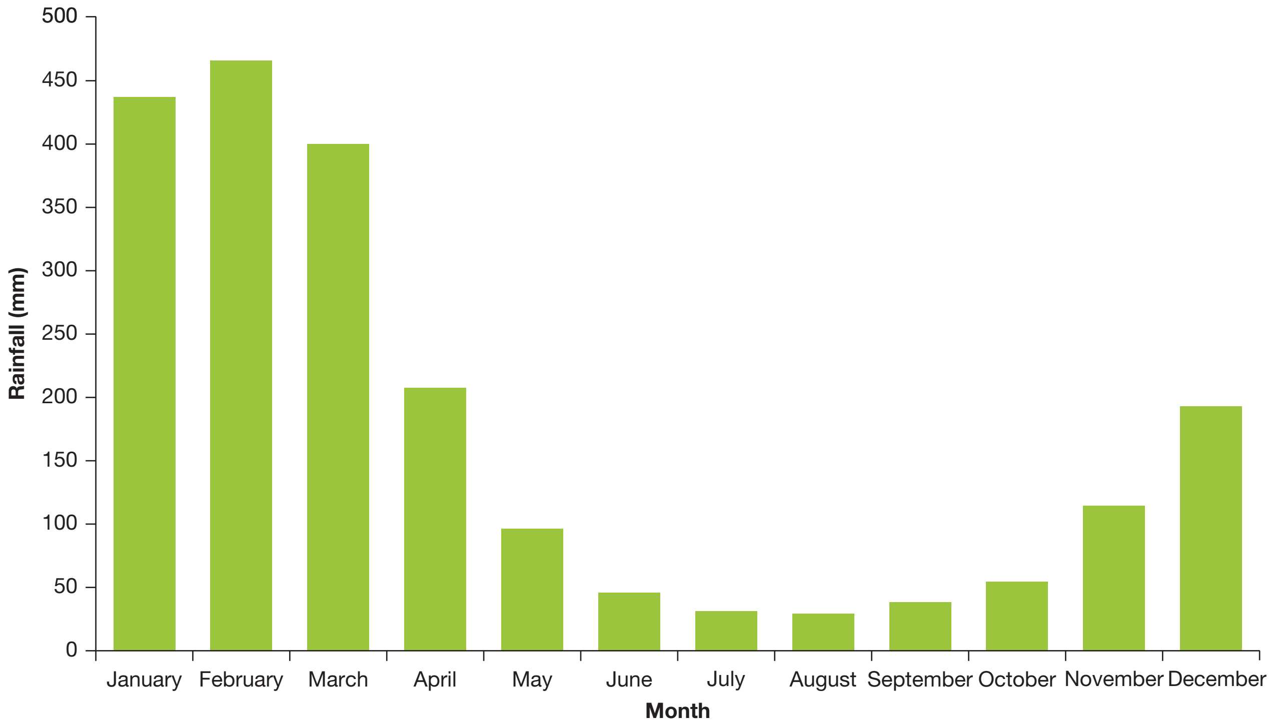
Step 3

For each column, mark the meeting point of the two pieces of information with a dot, then use your ruler to neatly complete the column. Shade it in using colour.

Step 4

Label the vertical and horizontal axes and give the graph a title. Include a key if necessary.

FIGURE 1.19 Mean monthly rainfall for the years 1871 to 2016, Cardwell, Queensland



Source: © Bureau of Meteorology

Step 5

Provide the source beneath your graph, to enable the reader to locate the source data if they wish.

Step 6

This same data could also be represented using a bar graph. In a bar graph, the columns would be oriented horizontally rather than vertically, but the ruled axes, labels, spacing, title and source would remain essential elements.

1.10 Activities

learnon

1.10 Quick quiz on	1.10 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2	–	–

1. Using the data in the table below, **construct** your own graph of average monthly rainfall for Innisfail, Queensland.

Mean rainfall (mm) for the years 1881 to 2016, Innisfail, Queensland

Statistics	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean rainfall (mm) for years 1881 to 2016	507.3	590.1	662.2	456.3	302.2	189	137.6	116.9	86.1	87.7	157.9	262.6

Source: © Bureau of Meteorology

2. Once you have constructed your graph, answer the following questions.
   a. **Name** the month with the most rainfall.
   b. **Name** the driest month.
   c. Imagine you are a filmmaker, planning to film on location in Innisfail for three months. As rain would cause problems for your filming schedule, **identify** the months that would be best for your requirements.

Answers and sample responses are available in your digital formats.

LESSON 1.11 Drawing a line graph

LEARNING INTENTION

In this lesson you will learn how to construct line graphs.

1.11.1 What is a line graph?

A line graph displays information as a series of points on a graph that are joined to form a line. They can show a single set of data, or they can show multiple sets.

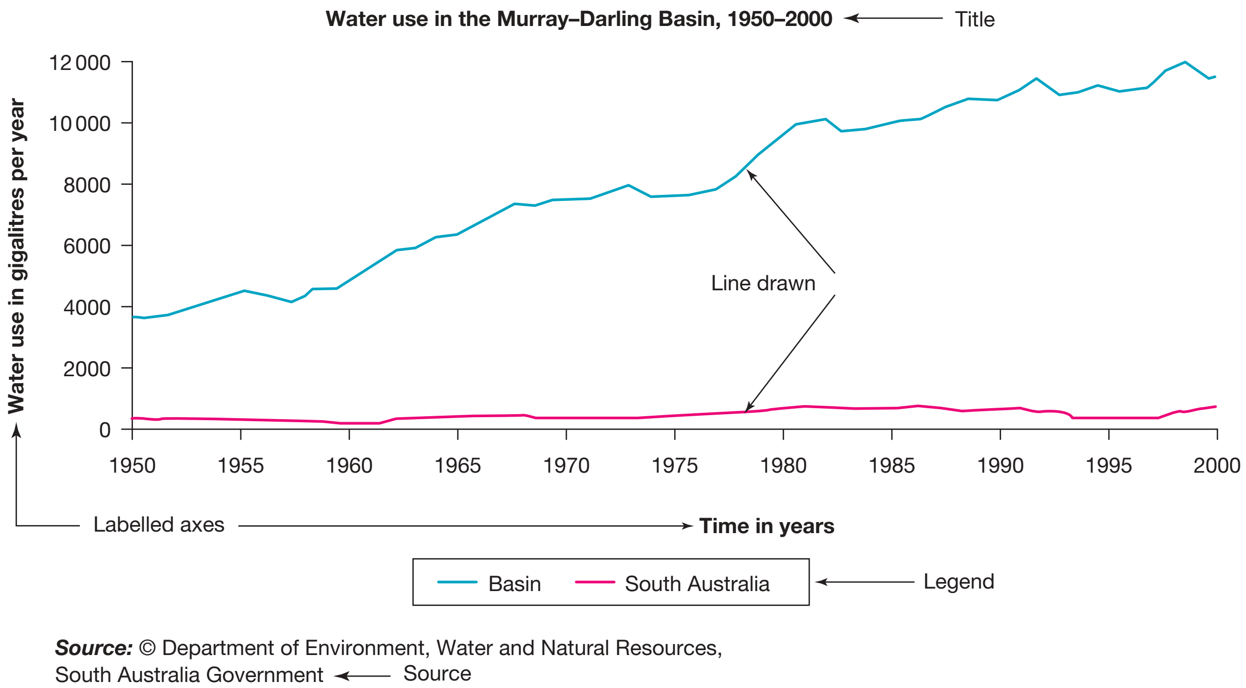
How are line graphs useful?

Line graphs are very useful to show change over time. They can show multiple sets of data based on a common theme, such as water use in the Murray–Darling Basin compared to water use in South Australia (see figure 1.20). This enables us to compare similarities and differences between two sets of data at a glance.

A good line graph has:

- been drawn in pencil
- an appropriate scale to show the data clearly
- labelled axes
- small dots joined by a line to make a smooth curve
- a legend, if necessary
- a clear and accurate title that explains the purpose of the graph
- the source of the data.

FIGURE 1.20 Water use in the Murray–Darling Basin



What is the application of line graphs in science?

Line graphs are very useful in science to show change over time for continuous data, such as the increase in temperature when heating water with a Bunsen burner. Line graphs can show a single or multiple sets of data, which allows comparison and trends in data to be observed.

1.11.2 How to complete a line graph

Materials

- data
- graph paper
- pencil
- ruler

Model

TABLE 1.9 Use of rainwater tanks by household in Australia, 2001–2010

Year	Use of rainwater tanks by household (%)
2001	16
2004	17
2007	19
2010	26

Method

Step 1

Select the data you wish to compare or interpret (table 1.9).

Draw a horizontal and vertical axis using a ruler.

Evenly space and then label the years along the horizontal axis. Look carefully at your range of data and work out appropriate increments for the vertical axis, then evenly space and label this information on the axis. Start at zero where the axes join. For the data in table 1.9, an increment of 5 percentage points would be appropriate.

Step 2

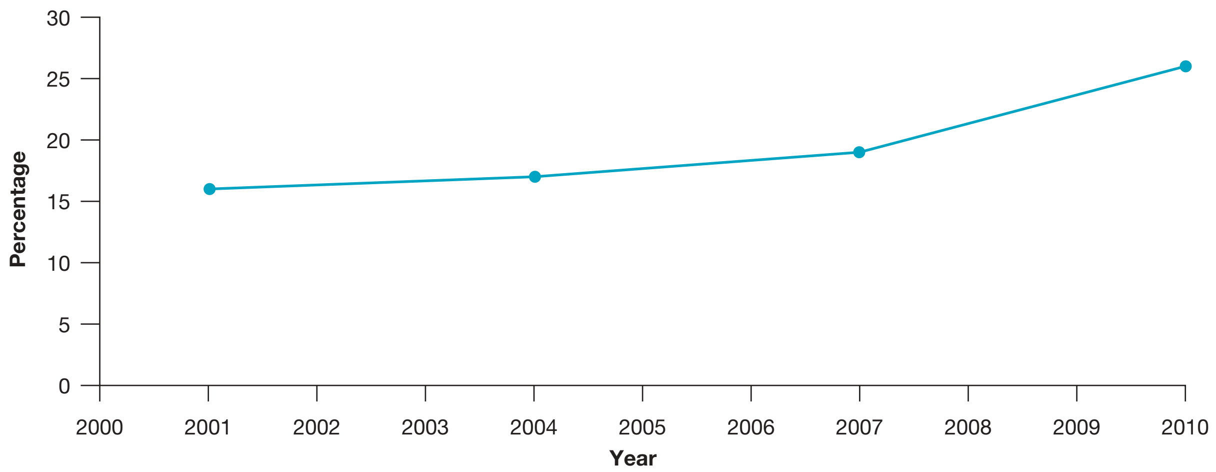
Label the *x*- and *y*-axes. In this case, the *x*-axis would be labelled 'Year', and the *y*-axis would be labelled 'Percentage'.

Plot the statistics. Draw a dot at the point where the year on the horizontal axis meets the relevant position on the vertical axis. Once you have plotted all the statistics, join the dots. This can be done freehand or using a ruler.

Step 3

Add a title and a source to the graph.

FIGURE 1.21 Use of rainwater tanks by household in Australia, 2001–2010



Source: © Australian Bureau of Statistics

1.11 Activities

learnon

1.11 Quick quiz on	1.11 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1	–	–

1. Use the data in the table below to create a line graph.

Daily residential water consumption for South Australia

Year	Daily residential water consumption (litres)
2001	539
2002	502
2003	532
2004	460
2005	465
2006	440
2007	413
2008	410
2009	395

Referring to your graph, **apply** your skills to answer the following questions.

a. In which year is water consumption lowest?
b. **Describe** the pattern shown by the graph.
c. **Suggest** some reasons that might explain the changes from 2001 to 2009.
d. When water restrictions were lifted in 2011, **predict** what happened to water consumption when water restrictions were lifted in 2011.
e. If the government made every household adopt water saving measures in the coming year, **suggest** what might happen to water consumption.
f. Find statistics for water consumption for your area and **compare** them to those from another area.
g. **Explain** how useful your graph was in helping you understand the changes that occurred to water consumption in South Australia compared to reading a table of figures.

Answers and sample responses are available in your digital formats.

LESSON 1.12 Constructing a pie chart

LEARNING INTENTION

In this lesson you will learn how to construct pie charts.

1.12.1 What is a pie chart?

A pie chart, or pie graph, is a graph in which slices or segments represent the size of different parts that make up the whole. The size of the segments is easily seen and can be compared. Pie charts give us an overall impression of data.

How are pie charts useful?

Pie charts are useful for comparing proportions of categories. However, if there are more than eight segments, the graph becomes difficult to read and it is better to use a bar graph. Unlike line graphs, pie charts are not useful for showing a trend over time.

A good pie graph:

- has a clear and accurate title that explains the purpose of the graph
- has segments that are either labelled directly or indicated by means of a colour key
- includes percentages or raw figures
- has segments drawn clockwise from largest to smallest, starting at 12 o'clock with the largest and finishing at 12 o'clock with the smallest, unless there is 'other', which is always last
- includes the source of the data.

What is the application of pie charts in science?

Pie charts are used in scientific applications when a quick and easily understood representation of data is required. Pie charts are usually easily understood even if an understanding of the science behind the data is not understood, and so are effective in communicating results of discrete data that are part of a whole.

1.12.2 How to complete a pie chart

Materials

- paper
- pencil
- protractor
- ruler
- coloured pencils
- data set — in this case, energy generated from renewables in New Zealand (table 1.10)

Model

TABLE 1.10 Percentage of electricity generated from renewables in New Zealand by energy source (2022)

Renewable energy	Percentage
Hydro	60
Bioenergy and solar	20
Wind	5
Geothermal	15

Note: In 2022, more than 80% of all electricity generated in New Zealand came from renewable resources.

Method

Step 1

Order the statistics from largest to smallest. If there is an 'other' category, put it last.

The largest amount of renewable energy is generated by hydro so it is at the top of the table, as shown in table 1.11.

TABLE 1.11 Percentage of electricity generated from renewables in New Zealand by energy source (2022)

Renewable energy	Percentage (%)
Hydro	60
Bioenergy and solar	20
Geothermal	15
Wind	5

Step 2

If there are raw figures, convert them to percentages. You divide each category by the total figure and multiply by 100.

The categories in our table are already percentages and add to 100%.

Step 3

Convert the percentage to degrees of a circle by multiplying by 3.6. (100 per cent of the circle = 360 degrees, so 1 per cent of the circle = 3.6 degrees.)

TABLE 1.12 Converting percentages to degrees in circle

Renewable energy	Percentage	Degrees in circle (percentage × 3.6)
Hydro	60	216
Bioenergy and solar	20	72
Geothermal	15	54
Wind	5	18

Step 4

Using a protractor or digitally, construct a circle to fit your page. Draw a straight line from the centre of the circle vertically to the top of your circle (the '12 o'clock' point).

Step 5

Use the protractor to mark the first and largest segment, working clockwise. To do this, place the 0 degrees line on the protractor along the line you have just drawn. Now mark the second-largest group. Use the protractor to mark each of the other segments in descending size, marking the 'other' category last.

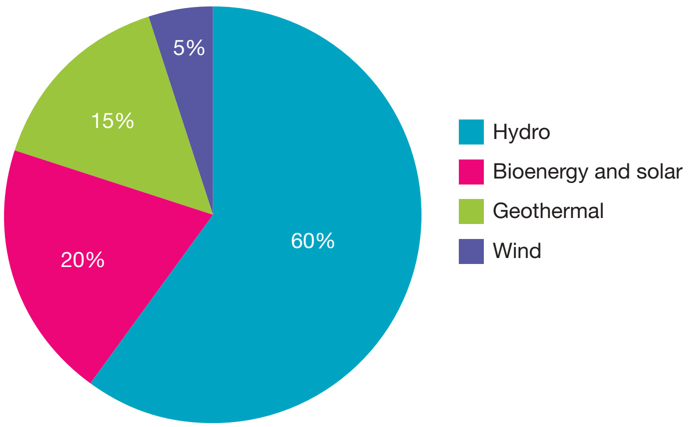
Step 6

Label and colour each segment, making sure you include the percentage.

Step 7

Provide a clear title and source.

FIGURE 1.22 Percentage of electricity generated from renewables in New Zealand by energy source 2023



Source: New Zealand Ministry of Business, Innovation and Employment 2023

1.12 Activities

learnon

1.12 Quick quiz on	1.12 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1	–	–

1. Use the data in the table below to **construct** a pie chart.

Source of electricity worldwide, 2023	
Source of electricity	**Percentage**
Coal	35.5
Wind and solar	13.3
Natural gas	22.5
Nuclear	9.1
Hydro	14.3
Bioenergy	2.3
Other	3

Once you have created your pie chart, apply the skills you have developed to answer the following questions.

a. **Name** the most common source of electricity globally in 2023.
b. **State** whether renewables or non-renewables were the main source of electricity in 2023.
c. **Name** a renewable source of energy that is part of the 'other' category.
d. In Iceland, 70 per cent of all electricity is produced from hydropower and 30 per cent is produced from geothermal power. Is this similar to or different from the world trend? **Explain**.

Answers and sample responses are available in your digital formats.

LESSON 1.13 Using a spreadsheet

LEARNING INTENTION

In this lesson you will:
- create, label and use formulas in a spreadsheet
- insert and label graphs to analyse data.

1.13.1 How do you use a spreadsheet to record, analyse and graph your results?

Spreadsheets, through programs such as Excel, provide very powerful ways to identify trends and patterns in your data. They allow data to be recorded in cells to format tables, and allow quick analysis of data and the creation of different types of graphs.

Why is it important to use spreadsheets?

Spreadsheets are a way of effectively recording data gathered during science investigations. This data can then be represented as a graph in the spreadsheet to show results and trends. These graphs make the results more easily understood and analysed.

What is the application of spreadsheets in science?

Spreadsheets are used in science applications to record and analyse large amounts of data. This data is often recorded from various types of electronic probes, such as temperature, mass or pressure probes. Spreadsheets are used in the medical field to record patient data and show it graphically. Many industrial processes are also continually monitored and the readings recorded in a spreadsheet.

1.13.2 How do you use a spreadsheet?

Materials

- data from an investigation or another secondary source
- a spreadsheet

Method

Step 1

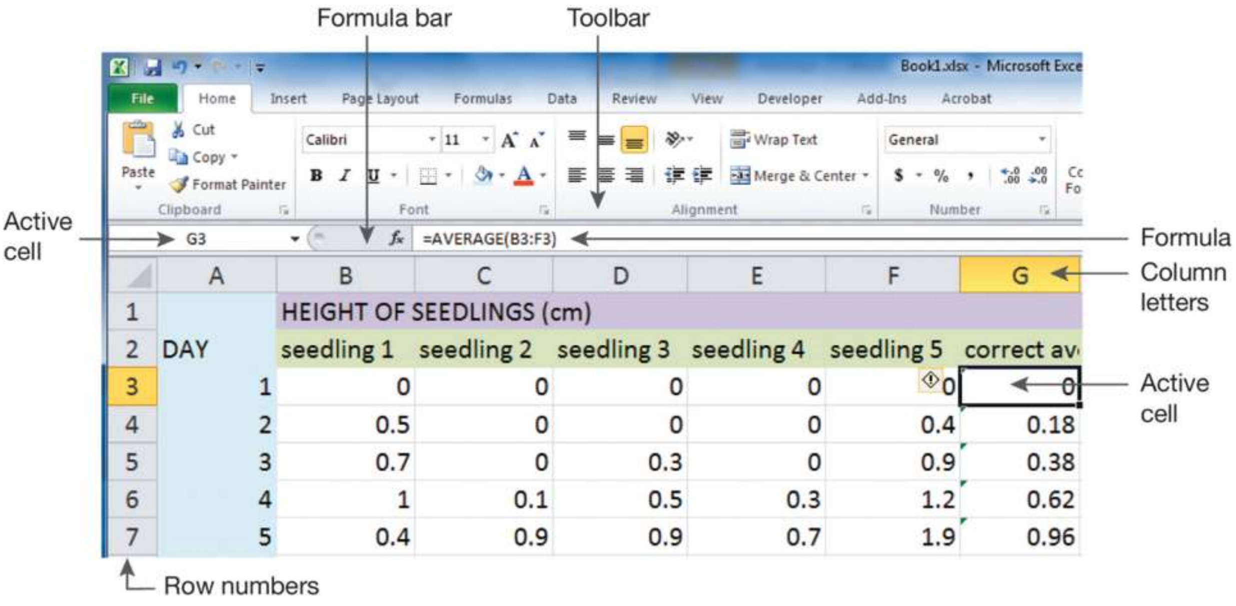
Change the title of your spreadsheet by selecting the tab at the bottom of the spreadsheet labelled 'Sheet 1'.

Step 2

Decide on titles for the rows (1, 2, 3, etc.) and columns (A, B, C, etc.) of your spreadsheet.

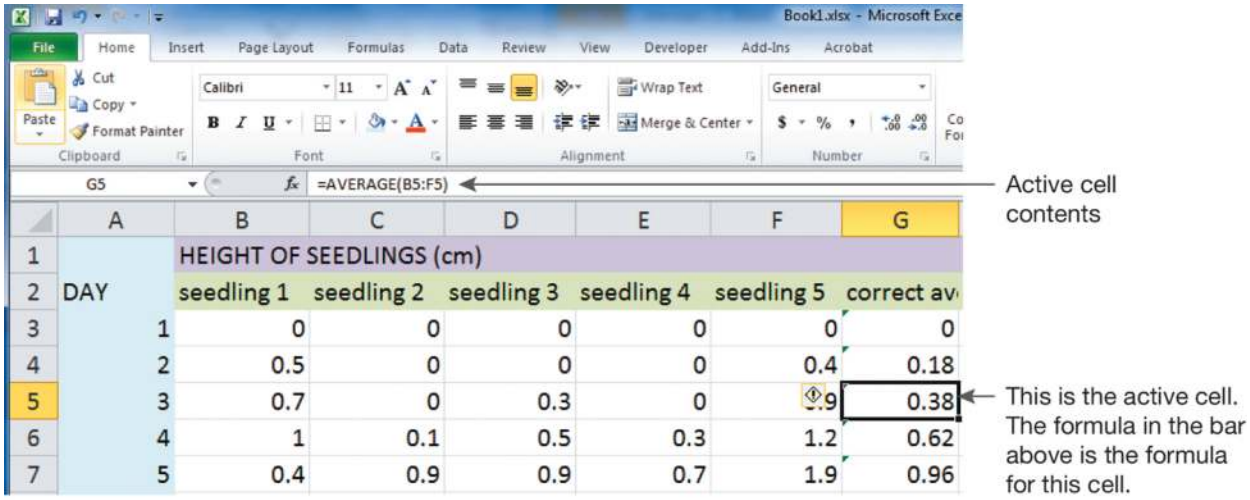
Step 3

Transfer your data into the spreadsheet.



Step 4

If you want to do calculations on the data in a spreadsheet, you need to enter a formula. In most spreadsheet programs, a formula starts with an equal sign (=). If you want the total of cell A2 and cell B2 to appear in cell C2, you would type the formula '=A2+B2' in cell C2, and then press the Enter key. If you want to calculate the average of a set of cells, for example, cells B5, C5, D5, E5 and F5, you would type =AVERAGE(B5:F5).



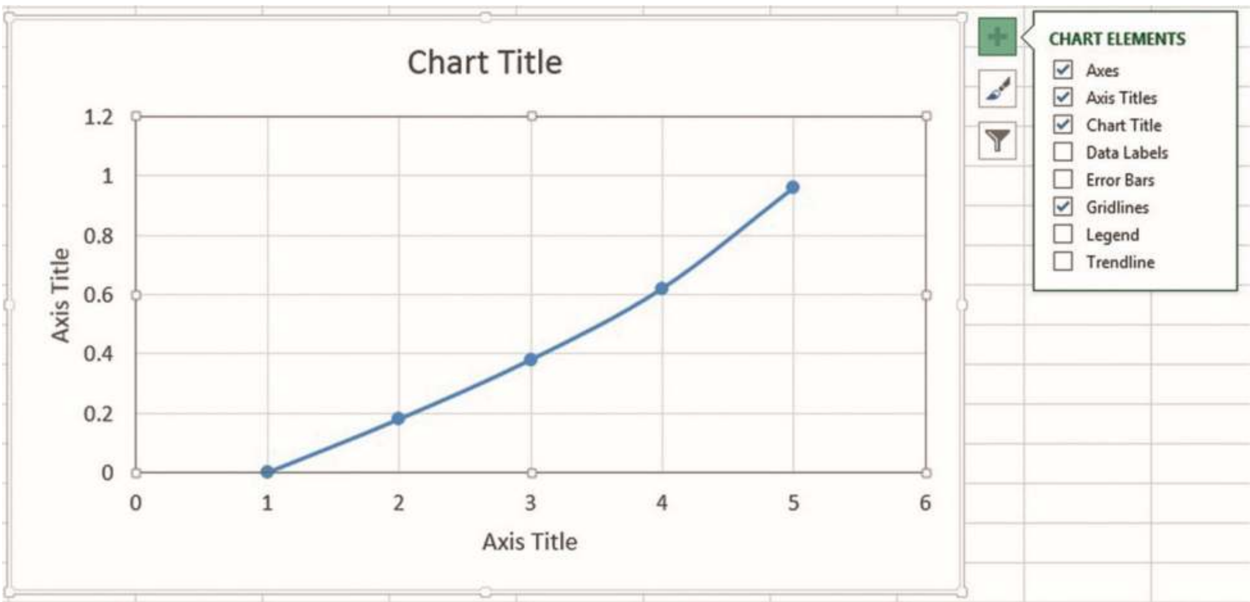
There are many other formulas that can be used, depending on your requirements.

The symbols used for mathematical operations in spreadsheets are:

- + for addition
- – for subtraction
- * for multiplication
- / for division.

Step 5

Create graphs by selecting the data, then clicking Insert and selecting the type of graph you want to produce. Once the graph has been created, use the Layout tab to add axis labels and a title for your graph.



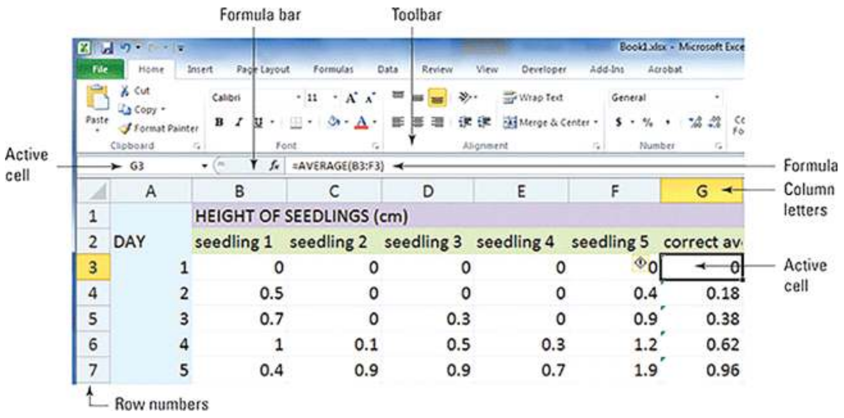
1.13 Activities

learnon

1.13 Quick quiz on	1.13 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 4	–	–

1. Look at the section of a spreadsheet presented below.



   a. MC **Identify** what cell G3 contains.
      A. The result of the average calculation for cells B3, C3, D3, E3 and F3
      B. The result of the average calculation for cells B4, B5, B6
      C. The result of the average calculation for cells H1, H2, H3
   b. **Identify** whether cell E2 contains a value or a label.
   c. If the formula in cell G4 is AVERAGE(B4:F4), what would be the formula in:
      i. cell G5
      ii. cell G6?
2. The following table shows the results of an experiment that tested the amount of time taken for eucalyptus oils and other substances (0.1 mL of each) to evaporate at a constant temperature. The experiment was done twice.

Time taken to evaporate different substances

Substance	Time (s)	
	Trial 1	Trial 2
Methylated spirits	4.17	1.85
Turpentine	63.48	43.02
Water	54.42	57.05
Oil from *E. rossi*	195.92	191.23
Oil from *E. nortonii*	103.99	105.39

   a. Enter the data into a spreadsheet.
   b. Use the spreadsheet function to **calculate** the average time that each substance took to evaporate.

3. The following table shows the distance travelled by Leo at 3-second intervals during a 100 m sprint. The data were recorded during the sprint by attaching a paper tape to Leo's waist. As he ran, the tape was pulled through a timer that printed a dot every 3 seconds.

Distance and speed travelled in 3-second intervals

Time (s)	Distance travelled in time interval (m)	Average speed for time interval (m/s)
0	0	
3	35	
6	25	
9	15	
12	15	
15	10	

a. Enter the data into a spreadsheet. **Calculate** the average speed travelled in each 3-second interval by applying a formula to the first cell in the column, and then copying it down. Remember that average speed can be calculated by dividing the distance travelled by the time taken:

$$\text{Speed} = \frac{\text{distance}}{\text{time}}$$

b. **Calculate** Leo's average speed over the total time, correct to 1 decimal place.

4. The following data was collected by two car servicing centres in Canberra, at the request of a student. The table shows the level of carbon monoxide and carbon dioxide emissions (as a percentage of total emissions) from cars of various ages.

Carbon monoxide and carbon dioxide emissions of cars by year of manufacture

Year car manufactured	Carbon monoxide (%)	Carbon dioxide (%)
1977	3.17	11.8
1983	2.48	13.6
1985	3.7	11.4
1987	1.6	13.1
1989	1.08	10.2
1996	0.19	15.2

a. Enter the data into a spreadsheet and **construct** a graph to display these results.

b. Create formulae to work out the average carbon monoxide and carbon dioxide emissions for:

i. cars manufactured up to 1985

ii. cars manufactured from 1987 onwards.

c. Car manufacturers were required to install catalytic converters in cars made after 1986. Catalytic converters cut down carbon monoxide emissions by converting some of the carbon monoxide to carbon dioxide. What can you **deduce** from this data about the success of catalytic converters?

Answers and sample responses are available in your digital formats.

LESSON 1.14 Problem solving

LEARNING INTENTION

In this lesson you will use a range of tools to think about problems and possible solutions.

1.14.1 Thinking tools to generate ideas

One of the most commonly used thinking tools to come up with ideas is brainstorming. This involves writing down all the ideas on a board or on a piece of paper, then choosing some of the ideas to investigate further. Other idea-generating tools include cluster maps and thinking routines such as Think, Puzzle, Explore.

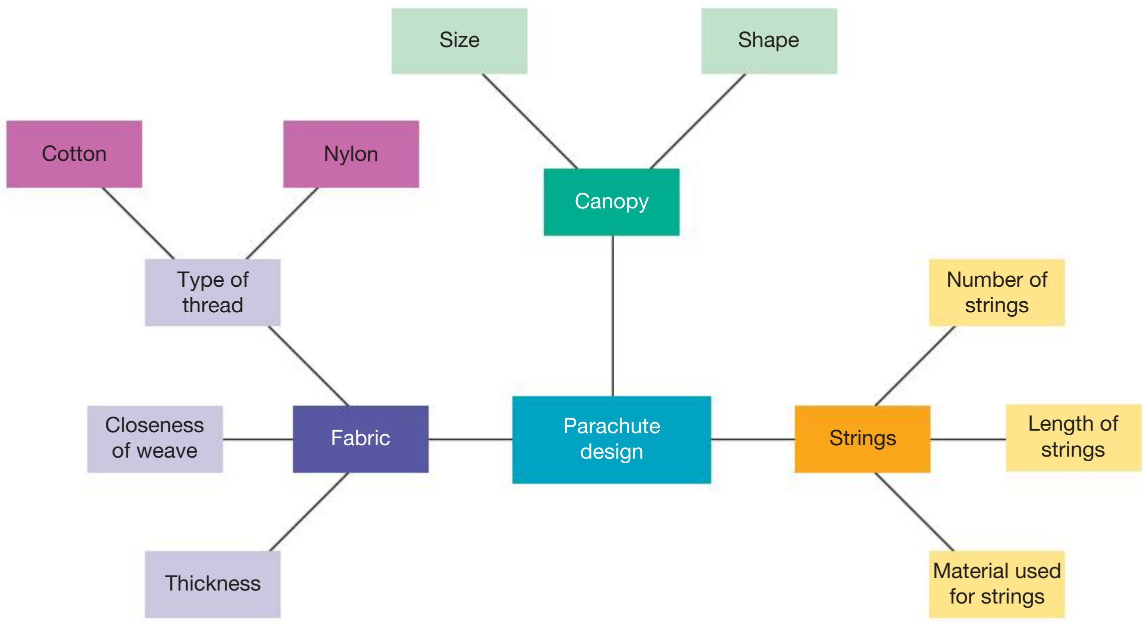
1.14.2 Stimulating ideas: Cluster maps

A cluster map starts with a central concept, then lines are drawn out to link to related ideas. Each of the bubbles around the central topic can itself have other ideas linked to it. Use the following steps to construct a cluster map.

1. Think of a topic and write it in the middle of a sheet of paper.
2. Around your topic, write down any ideas that link with it. Draw lines from the ideas to your topic.
3. Write down new ideas that are related to your first ideas, and link them with lines.

The cluster map in figure 1.23 was created by a student who chose the following problem for her project 'Which parachute design will slow down a toy's fall most effectively?'

FIGURE 1.23 A cluster map



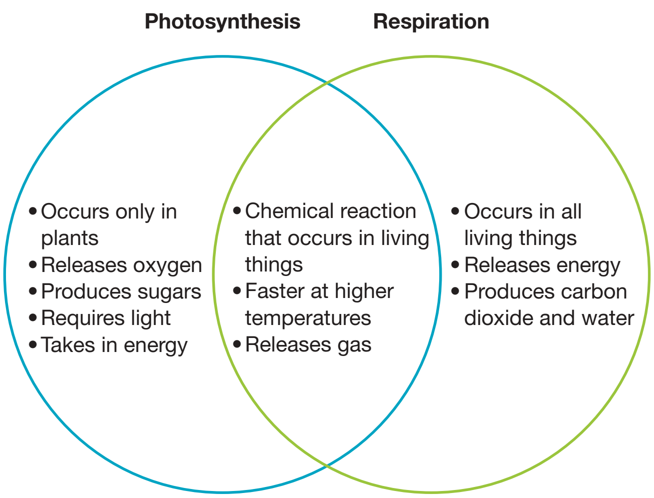
1.14.3 How ideas overlap: Venn diagrams

Venn diagrams are often used in mathematics, but they can be useful to scientists as well to show common points between different ideas or concepts. Use the following steps to draw a Venn diagram for two topics.

1. Draw two overlapping circles with the topic written above each circle.
2. In each circle, write down ideas that relate to each topic.
3. Write ideas that relate to both topics in the overlapping section.

Figure 1.24 shows a Venn diagram that illustrates some of the similarities and differences between respiration and photosynthesis.

FIGURE 1.24 A Venn diagram



1.14.4 Thinking about solutions

A thinking routine can be useful when trying to find a creative solution to a problem. It involves asking specific questions, with the purpose of opening up your thinking and considering other perspectives. For example, when trying to develop possible solutions to a problem, you might use a Think, Puzzle, Explore thinking routine. This involves answering the following questions:

- What do you already know about this problem?
- What puzzles you about this problem? What are some questions you have about the problem?
- What are some ways that you could explore the things that puzzle you?

FIGURE 1.25 Thinking routines can be useful when trying to find a solution to a problem.

There are lots of different thinking routines. You might be familiar with Think, Pair, Share, which requires you to think about a question on your own, then discuss your ideas with a partner and finally share your thinking with the whole class. Taking a systematic approach to thinking about a problem may help you to think about the problem more deeply and avoid closing off ideas before they have been properly examined.

1.14.5 Evaluating solutions

When evaluating the solution to a problem, it is important to know what the criteria are. Is there a budget to consider? How much time is available? Is there a minimum performance requirement? Is your solution safe?

Activity

Build the tallest tower from spaghetti and marshmallows

Problem

Your teacher will provide you with 20 spaghetti strands, 4 marshmallows, 1 m of sticky tape and 1 m of string. Your task is to make the tallest possible tower using only this equipment. You may use scissors to cut the string and tape.

Questions

1. What were the criteria for this problem? Evaluate your solutions against these criteria.
2. Additional criteria could have been added; for example, that the tower must remain standing even if the table on which it is sitting is shaken from side to side. How would this change your evaluation?
3. Outline why it is important to know the criteria against which the solution will be evaluated before starting to work on a solution for a problem.

SCIENCE INQUIRY: Explaining solutions using cause-and-effect language

In science, explaining solutions to problems often involves identifying and clearly describing cause-and-effect relationships. This means stating what causes or leads to a particular effect or result, and using evidence or observations to support your explanation.

For example, consider the 'spaghetti and marshmallow problem', where groups are tasked with building a tall tower using only spaghetti and marshmallows. You might observe that groups who started with a wider base for their towers were more successful in building taller structures. An explanation for this could be:

> 'The towers with a wider base are more stable because they distribute the weight of the structure over a larger area. This reduces the likelihood of the tower collapsing as its height increases.'

This explanation identifies the cause (a wider base) and the effect (a more stable tower), supported by reasoning and observations. By using cause-and-effect language, you provide a logical and clear justification for your findings.

Explaining solutions in science is not just about describing what happened, but also about understanding and communicating why it happened. This skill is essential for drawing meaningful conclusions, solving problems, and applying scientific principles in real-world context.

1. Why does starting with a wider base make a tower more stable? How does this relate to the concept of weight distribution?
2. Describe a scenario where a narrower base might be advantageous in a different type of problem or structure. What would be the cause-and-effect relationship in this case?
3. In your own words, explain why marshmallows are useful for connecting pieces of spaghetti in the tower-building challenge. Use cause-and-effect language in your answer.
4. If a tower collapses when it reaches a certain height, what could be the cause? How would you explain this observation using scientific reasoning?
5. Think of a real-world example where cause-and-effect reasoning is used to explain structural stability (e.g. building bridges or skyscrapers). How would you explain the relationship between design choices and stability?
6. If you were designing an experiment to test different shapes of tower bases, what evidence would you collect to support your conclusions? How would you use cause-and-effect language to explain your findings?

Evidence-based arguments can be constructed to support conclusions or evaluate claims, including consideration of ethical issues and protocols associated with using or citing secondary data or information (VC2S8I07)

KEY IDEA

- Explanations require cause-and-effect language.
- The cause is what leads to the effect.
- Examples of words that can be used to link the cause and effect include: leads to, causes, is produced by, consequently.

1.14 Activities

learnon

1.14 Quick quiz on	1.14 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 4, 7	3, 5	6, 8

Remember and understand

1. MC **Identify** what a Venn diagram consists of.
   A. Boxes linked by arrows
   B. Circles linked by lines
   C. Concentric circles
   D. Overlapping circles
2. MC **Identify** which of the following would not be used to link the cause and effect in an explanation.
   A. Leads to
   B. Consequently
   C. Is produced by
   D. In addition to
3. **Identify** some reasons for using thinking routines when thinking about a problem.
4. Rosie has noticed that her dog comes and sits next to her in the kitchen each time she prepares a sandwich. Use cause-and-effect language to **explain** this observation.

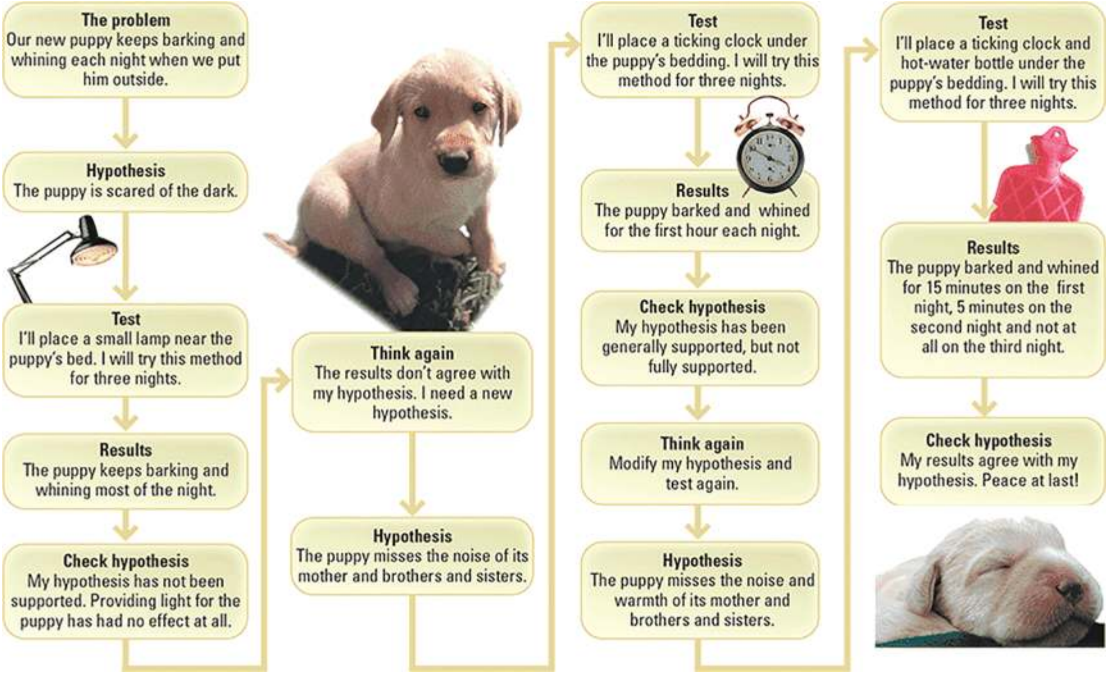
Apply and analyse

5. Imagine that you are going on a three-day adventure camping trip with your friends. You have been tasked with the problem of organising the food for the trip. You and your friends will have to carry all the food you need for three days in your backpacks.

   What criteria could be used to **evaluate** the solution to this problem?

Evaluate and create

6. **Interpret** the flow chart to answer the following questions.



   a. **State** what the problem was to be solved.
   b. **Identify** what action was taken when the first and second hypotheses were not supported.
   c. **State** which variable was used in each of the three experiments.
   d. Do you think each experiment was a fair test? **Explain**.
   e. **Suggest** what other explanations could account for the change in the behaviour of the puppy in the final experiment.
7. **Construct** a Venn diagram with one circle labelled 'Plants' and the other 'Animals', and complete it using features of plants and animals.
8. Use the Think, Puzzle, Explore thinking routine to think about the following problem: How could we encourage more students to use public transport, walk or ride their bike to school as an alternative to being driven by their parents.

Answers and sample responses are available in your digital formats.

LESSON 1.15 Review

1.15 Success criteria

Tick the column to indicate that you have completed the lesson and how well you think you have understood it using the traffic light system.

(**Green:** I understand; **Yellow:** I can do it with help; **Red:** I do not understand)

Lesson	Success criteria	Green	Yellow	Red
1.2	I can make observations using my senses.			
	I can measure quantities, including length, mass, temperature and volume, using appropriate scientific equipment.			
1.3	I can read and record measurements accurately.			
1.4	I can identify questions and problems that can be investigated scientifically.			
	I can make predictions based on scientific knowledge and observations.			
1.5	I can write aims and hypotheses.			
1.6	I can plan an experiment or investigation.			
1.7	I can identify independent, dependent and controlled variables.			
1.8	I can conduct an investigation, either in a group or individually.			
1.9	I can organise data into tables and graphs.			
1.10	I can construct simple column and bar graphs.			
1.11	I can construct a simple line graph.			
1.12	I can construct a simple pie graph.			
1.13	I can create, label and utilise formulas in a spreadsheet.			
	I can insert graphs to analyse data.			
1.14	I can use a range of tools to think about problems and possible solutions.			

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Post-test	Topic 1 Post-test
eWorkbook	Topic 1 eWorkbook
Digital document	Key terms glossary

1.15 Activities

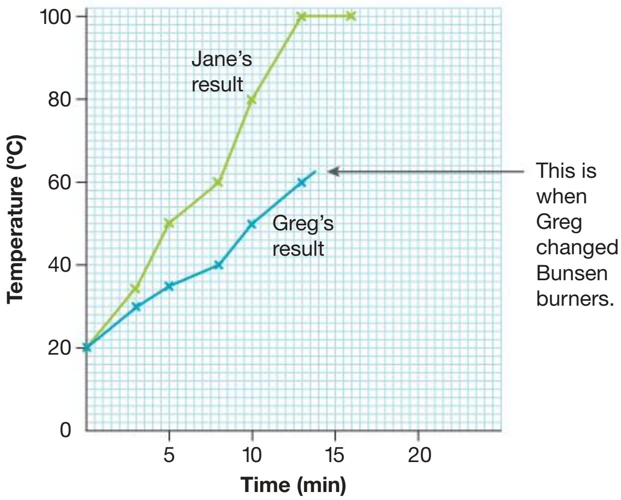
learnon

1.15 Review questions

LEVEL 1	LEVEL 2	LEVEL 3
1, 2	3, 4	5, 6

Remember and understand

1. Dante and Mary were walking past their neighbour's house when they noticed that a front window was broken. Dante told Mary that somebody had probably thrown a ball through the window. They had a closer look and noticed clothes scattered all over the floor and drawers open. Mary noticed some blood on the broken glass. She told Dante that the house had been burgled. Dante agreed and they called the police.
   a. MC **Identify** whether the statement 'Mary noticed some blood on the broken glass' is:
      A. an observation.
      B. a hypothesis.
      C. a conclusion.
      D. an inference.
   b. MC Who suggested a hypothesis?
      A. No one
      B. Dante only
      C. Mary only
      D. Both Dante and Mary
2. Jane and Greg decided to test how quickly water would boil when using either the yellow flame or blue flame of the Bunsen burner. They set up identical experiments, except that Jane used a blue flame and Greg used a yellow flame. Their results are graphed below.



   a. MC **Identify** the temperature of Greg's water when Jane's water reached 100 °C.
      A. 100 °C
      B. 60 °C
      C. 62 °C
      D. 70 °C
   b. MC Jane removed her beaker and Greg quickly placed his beaker over Jane's Bunsen burner. Assuming that the temperature of Greg's beaker did not drop while swapping Bunsen burners, **identify** at what time his water would boil.
      A. 17 minutes
      B. 22 minutes
      C. 15 minutes
      D. 18 minutes

Apply and analyse

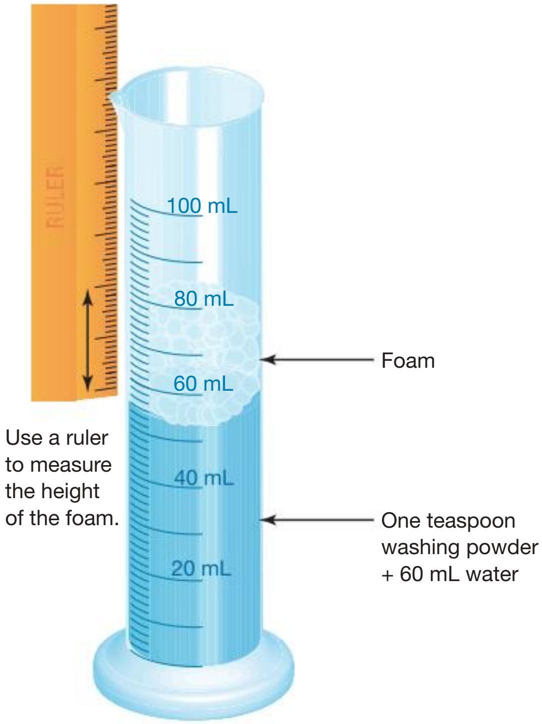
3. Singalia and Sallyana are two red panda cubs born at Sydney's Taronga Zoo. The table below shows their masses during their first 22 weeks. The image shows one of the cubs being weighed.

Week	Singalia	Sallyana
1	213	219
2	285	290
3	330	349
4	365	377
5	403	408
6	465	452
7	536	514
8	564	576
9	594	610
10	650	637
11	703	680
12	714	740
13	814	796
14	872	812
15	956	806
16	1111	786
17	1043	890
18	1130	1000
19	1163	1083
20	1182	1162
21	1225	1218
22	1335	1270

a. **Construct** a line graph showing both sets of data on the same set of axes. Use different symbols for the points for each panda and label each line with the panda's name. You may have to extend the vertical axis to fit the scale appropriately for the pandas' masses (or convert the masses to kilograms and plot in kilograms).
b. **Describe** the growth of each of the panda cubs, referring to your graph. How do they compare with each other?
c. **Assess** how long it took the cubs to double their mass measured in week 1.
d. Did the pandas grow at the same rate during the 22 weeks?
e. **Identify** which were the fastest and slowest growth periods for each panda.
f. **Identify** the age of each of the cubs when they reached 1 kg.
g. **Predict** the age at which each cub will reach 1.5 kg. **Explain** how you made your prediction. What assumption did you make to answer the question?

4. If you have a front-loading washing machine, you should use ‘low-sudsing’ washing powder, which produces less foam than other washing powders. Frank did the following experiment to compare how much foam was produced by three brands of washing powder.

- He put one teaspoon of each washing powder into separate 100-mL measuring cylinders.
- He added 60 mL of warm water to each measuring cylinder.
- He shook each measuring cylinder vigorously.
- He measured the height of the foam produced in each measuring cylinder using a ruler.



a. **Identify** the independent and dependent variables in Frank’s experiment.
b. **Identify** the variables that Frank controlled.
c. **Identify** the variables that could have been controlled better.
d. **Suggest** how Frank’s experiment could be made more reliable.

Evaluate and create

5. Huang and Rushi conducted an experiment to find out if radish plants grow better in the shade. They placed three plants under a veranda at the back of the house and another three in a sunny place in the front yard. All plants were planted in the same soil. Huang and Rushi watered each of the plants equally each day.
   a. **Assess** whether they conducted a fair test.
   b. How could Huang and Rushi improve the design of their experiment? List as many improvements as possible.
6. The boiling point of water changes with air pressure; for example, water boils at 100 °C at sea level, but may boil at a different temperature at the top of Mount Everest, where the air pressure is less than at sea level. The following table shows the boiling point of water at various air pressures.

Air pressure in kilopascals (kPa)	Boiling point of water (°C)
0	0
1	20
7	40
21	60
45	80
101	100
200	120

   a. Graph the data.
   b. **Describe** the shape of your graph.
   c. **Identify** the pressure of the atmosphere at sea level.
   d. Would it take a longer or shorter time to boil water at the top of Mount Everest, compared with the time it would take at sea level? **Explain** your answer.

Answers and sample responses are available in your digital formats.

on To test your understanding and knowledge of this topic, go to your learnON title at www.jacplus.com.au and complete the **post-test**.

2 Cells

CONTENT DESCRIPTION

Cell theory describes cells as the basic units of life; organisms may be unicellular or multicellular and have specialised structures and organelles (including cell walls, cell membranes, cytoplasm, nuclei containing DNA, mitochondria, ribosomes, chloroplasts and vacuoles) that perform specific functions (VC2S8U02)

Source: Victorian Curriculum F–10 Version 2.0

LESSON SEQUENCE

LESSON 2.1 Overview

2.1.1 Introduction

Cells are the basic units of all living things. The first cell appeared on Earth about 3.6 billion years ago. It is believed that bacteria known as thermophiles, living near hydrothermal vents in our oceans, may share some similar features to these ancestral cells.

On Earth today, there are many different types of **organisms**. Some of these organisms are made up of a single cell (**unicellular**), such as those of bacteria mentioned above, while others are made up of many cells (**multicellular**). The evolutionary twists and turns taken from single-celled organisms to the largest ever land animals, the sauropod dinosaurs, or to the tallest tree, the giant sequoia (*Sequoiadendron giganteum*), or to the largest colony of fungus, the humongous fungus (*Armillaria ostoyae*) spanning 8.9 square kilometres in Oregon, have been plentiful.

The cells that make up organisms differ not just in their number, but also in their size, shape and contents. The cell that makes up one type of unicellular organism may be different from that of another type of unicellular organism. The cells that make up multicellular organisms are also different. The structure of different types of cells and how they are organised within multicellular organisms are well suited to their specific tasks within the organism. No matter the difference, the features of the cell(s) that make up organisms all share the ultimate goal — to keep the organism alive.

FIGURE 2.1 A single cell (unicellular) organism

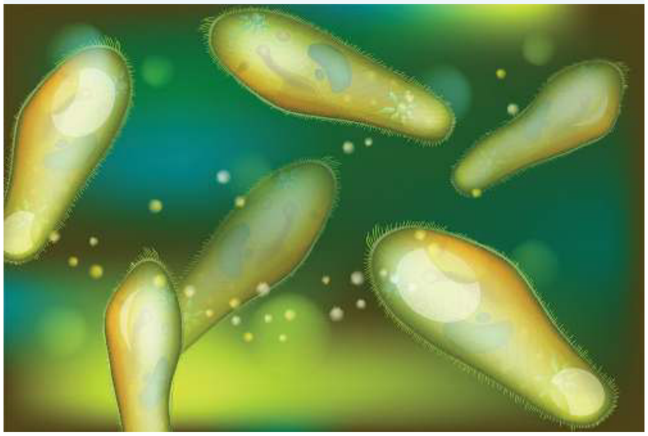


FIGURE 2.2 *Sequoiadendron giganteum.* The oldest tree of this species was over 3200 years, making it one of the oldest living organisms. They grow to an average height of 50–85 m, with trunk diameters ranging 6–8 m.

DISCUSSION

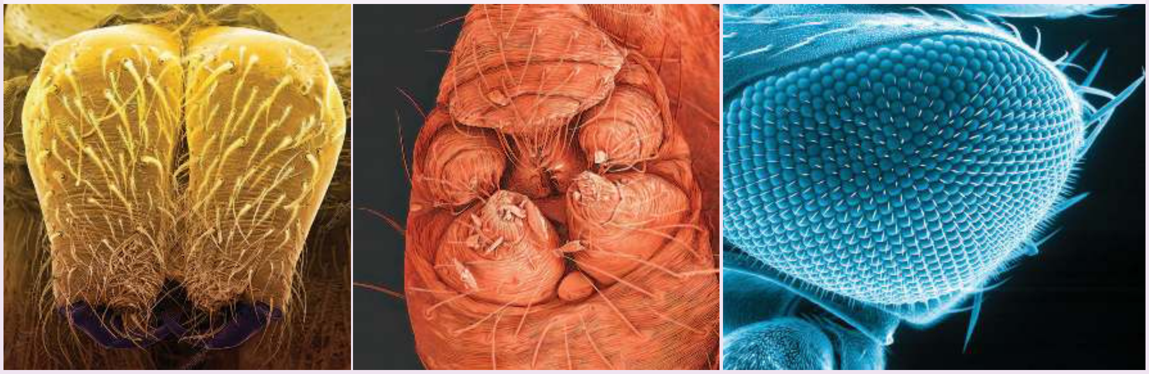
1. How can you make small things look bigger?
2. Which are bigger: animal cells or bacteria?
3. Why are beaches tested for the presence of the bacteria *E. coli*?
4. How does a cell become a clone?
5. Why is it that all cells do not look the same?

SCIENCE INQUIRY: Who am I?

Microscopes are responsible for opening a whole new world to us. They have allowed us to see beyond our own vision. The more developed these microscopes become, the more detail and wonder we are able to observe — but often, rather than answering our questions, they provide us with many more.

The three photos in figure 2.3 show parts of different animals. They were taken with a scanning electron microscope that has a large depth of field and a higher resolution. This means specimens can be magnified to look even bigger, allowing us to observe them with greater detail.

FIGURE 2.3 Different animal parts taken with a scanning electron microscope



Observe, think and share

1. Look carefully at the photos of each animal part in figure 2.3, and think about:
   a. what they could be
   b. what the purpose of the part may be
   c. what animal they may belong to.
2. Talk through your suggestions with a partner, adding all of the details that you have both observed onto a sheet of paper.
3. Two of these photos show parts of one type of animal, and the other image is from a different animal. Does that information change the way that you look at the details? Which animal do you think two of the parts belong to? Brainstorm to decide which animal the other part could belong to.
4. Suggest other sorts of information that may be helpful in determining which animals these parts belong to and what they are used for.

Investigable questions, reasoned predictions and hypotheses can be developed in guiding investigations to identify patterns, test relationships and analyse and evaluate scientific models (VC2S8I01)

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Pre-test	Topic 2 Pre-test
eWorkbooks	Topic 2 eWorkbook Student learning matrix
Practical investigation eLogbook	Topic 2 Practical investigation eLogbook
Digital document	Key terms glossary

LESSON 2.2 A whole new world

LEARNING INTENTION

In this lesson you will understand that our knowledge and understanding of cells has improved as a result of continued scientific investigation, human inventions and technological advancement. This work by scientists led to the creation of scientific theories such as the cell theory.

2.2.1 The discovery of cells

A whole new world was discovered just over 400 years ago when an English inventor and scientist used magnifying lenses to observe the basic units of which all living things are made. This led to a new way of thinking about living things that required a new scientific language, new classifications and new inventions.

In the seventeenth century, Robert Hooke looked at thin slices of cork under a **microscope** that he had made himself from lenses. He observed small, box-like shapes inside the cork. He called these little boxes **cells**. Microscopes opened up a whole new world that had never been seen before.

Carefully observing different organisms through microscopes showed that the organisms were all made up of cells. Observations also showed that many of these cells shared common features, such as the presence of a structure called the **nucleus**. This formed the basis of **cell theory**.

KEY IDEA

The word 'microscope' comes from the Greek words *micrós*, meaning 'small', and *skopein*, meaning 'to view'.

FIGURE 2.4 Timeline showing the development of the microscope and cell theory

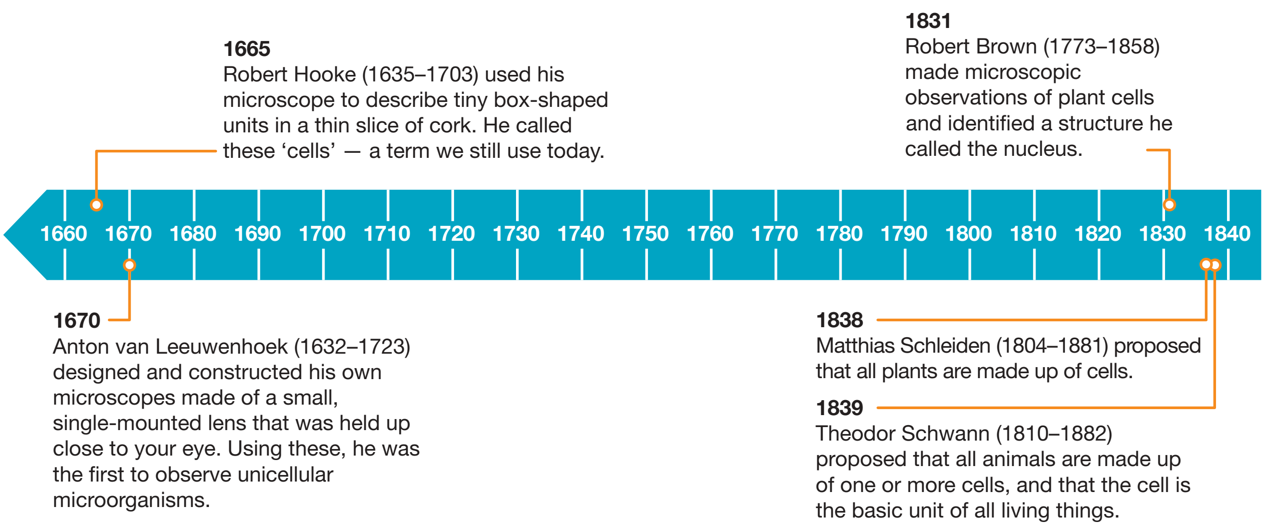
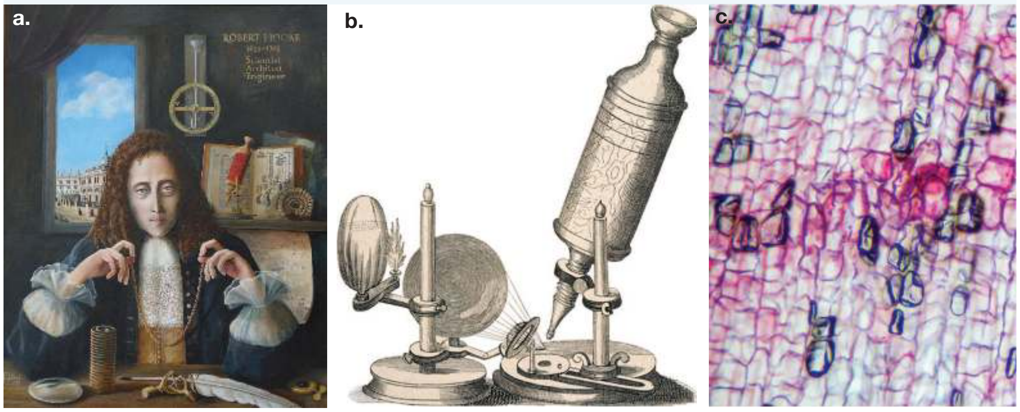


FIGURE 2.5 a. Robert Hooke **b.** Hooke created a microscope out of lenses **c.** Cells that make up cork.

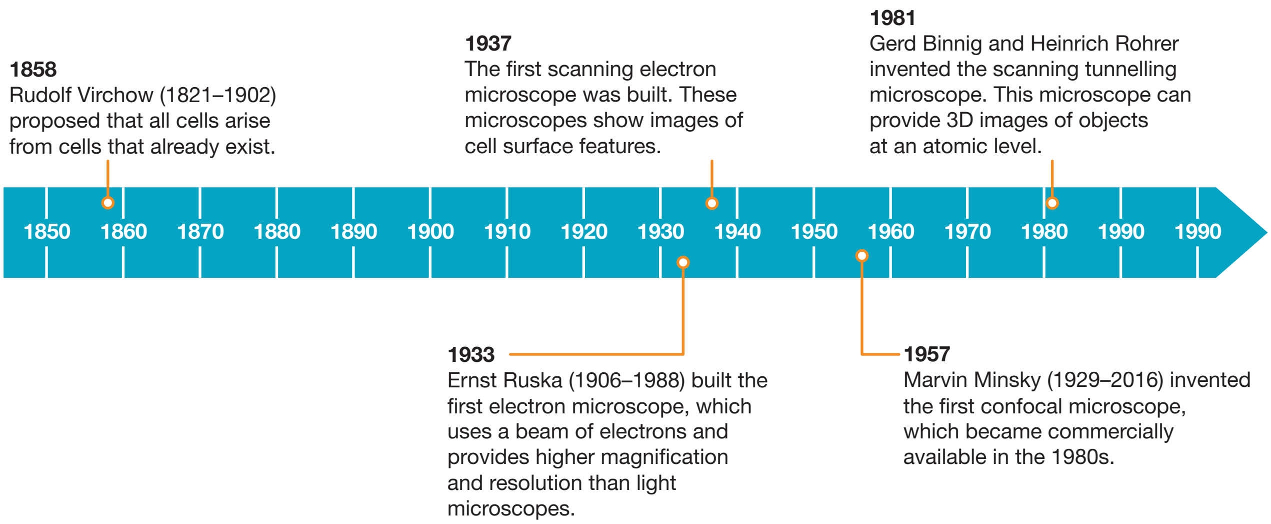


DISCUSSION

1. Have you used a magnifying glass to view an object? If so, what did you observe?
2. Do you think the image Robert Hooke observed was as clear as the image shown in figure 2.5c? Share and discuss your response with others.

As the magnification provided by microscopes increased, it was seen that although cells shared similar basic structures, there were also differences between them. Groups of organisms could be made up of cells that differed from the cells of other groups. Some organisms were made up of a single cell (unicellular), whereas others were made up of many cells (multicellular). Different types of cells were also observed within an individual multicellular organism.

FIGURE 2.4 *(continued)*



> **ACTIVITY: How technology changed cell studies**
>
> Our knowledge and understanding of cells have grown significantly over time, thanks to continued scientific investigation, inventions and advancements in technology.
> 1. How did the invention of the microscope change the way scientists studied life?
> 2. Why was the electron microscope such an important breakthrough for understanding cells?
> 3. What new discoveries about cells might still be made with even more advanced technology in the future?

2.2.2 Little, littler, littlest …

With the development of instruments such as microscopes, scientists needed to find words to describe some of the tiniest lengths and time scales in nature. They wanted some simple names to describe, for example, a billionth of a billionth of a metre.

Within the microscopic world, there is often a need to describe things in much smaller terms than the units of measurement that you already know, such as metre, centimetre and millimetre. In describing cells, other units of measurement, such as **micrometre** (μm, also called micron) and nanometre (nm), are often used.

FIGURE 2.6 Different units of measurement are used to describe different sizes.

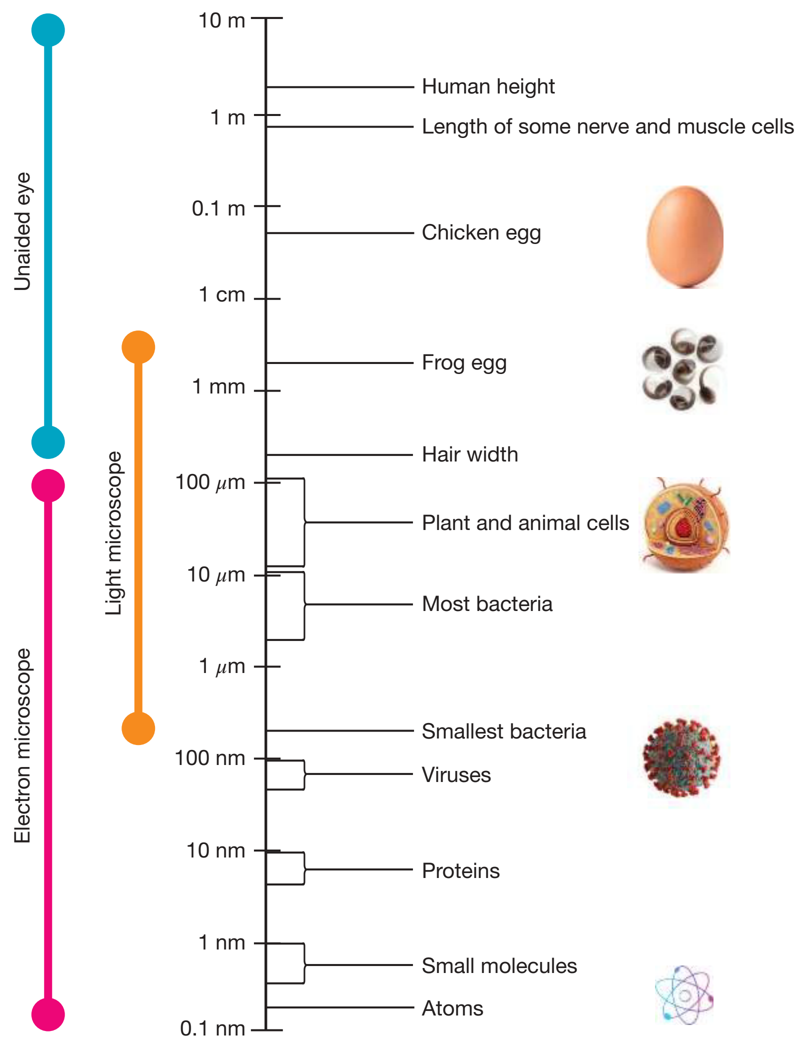


TABLE 2.1 Units of measurement that are often used to describe cells and molecules

Unit	Symbol	Number of units in 1 m
Millimetres	mm	1000
Micrometres	μm	1 000 000
Nanometres	nm	1 000 000 000

CASE STUDY: Scientists who study cells

There are many different types of scientists who study cells. Examples include bacteriologists, cell biologists, clinical microbiologists, cytologists, electron microscopists, genetic scientists and medical microbiologists.

SAMPLE PROBLEM 1: Evidence-based conclusions

Sam is a bacteriologist who studies *Mycoplasma genitalium*, the smallest known bacteria. In a talk to students, Sam is asked if she uses a microscope to see these small bacteria or whether she can see them without using a microscope.
Do you think Sam would need a microscope to see these bacteria? Use evidence to support your conclusion.

THINK

- The smallest bacteria are between 200 and 300 nm in size.
- The naked eye can only see things that are greater than 100 μm (or 100 000 nm).
- Since the bacteria are much smaller than 100 μm, Sam must use a microscope to see them.
- Sam would need to use an electron microscope.

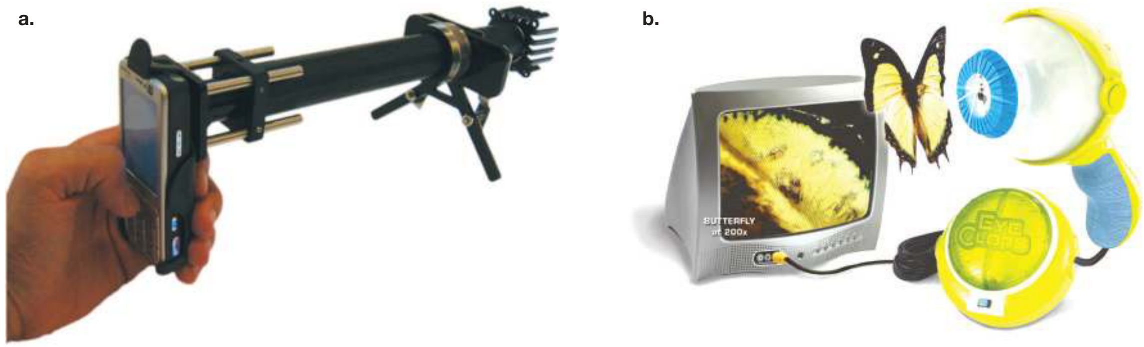
WRITE

Sam would need to use an electron microscope as the smallest bacteria are much too small to be seen with the naked eye. The smallest bacteria are less than 300 nm in size and the naked eye can only see things that are bigger than 100 000 nm (100 μm).

2.2.3 Present day

A new generation of three-dimensional microscopes are being developed that reveal even greater detail when observing objects than ever before. Superfast electron microscopes enable scientists to capture movements of atoms, and newly invented portable microscopes are becoming important field tools in research and diagnosis of diseases.

FIGURE 2.7 a. A portable microscope for spotting and tracking disease **b.** Looking like a grotesque eyeball, this handheld microscope magnifies specimens to 200 times their normal size.



SCIENCE AS A HUMAN ENDEAVOUR: The evolution of cell theory

Scientific models and theories are tools that help us understand the natural world. In the study of cells, scientists have developed and refined many models and theories over time. Early scientists such as Robert Hooke first observed cells using simple microscopes, leading to the development of the cell theory.

However, the theory changed as new evidence and technologies emerged. For example, the invention of the electron microscope allowed scientists to see the detailed structures inside cells, such as organelles, which were previously invisible. This new evidence deepened our understanding of how cells function and led to the discovery of cell processes such as mitochondrial energy production and DNA replication.

Scientific knowledge about cells continues to evolve. Modern tools, such as CRISPR and advanced imaging technologies, have opened new areas of research. Scientists can now study how cells communicate, how they grow and even how they can be manipulated to treat diseases.

1. Why do you think it is important for scientific theories, such as cell theory, to change over time as new evidence is discovered? How does this benefit our understanding of the natural world?
2. The development of new technologies, such as the microscope, has been crucial to advances in cell biology. How do you think future technologies might change the way we understand cells or their functions?

Scientific knowledge, including models and theories, can change because of new evidence (VC2S8H01)

2.2 Activities

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2.2 Quick quiz on | **2.2 Exercise**

LEVEL 1	LEVEL 2	LEVEL 3
1, 2	3, 5	4, 6

Remember and understand

1. Match the scientist with their cell discovery contribution in the table provided.

Scientist	Cell discovery contribution
a. Anton van Leeuwenhoek	**A.** Built the first electron microscope
b. Robert Hooke	**B.** Proposed that all plants are made up of cells
c. Robert Brown	**C.** Proposed that all animals are made up of cells
d. Matthias Schleiden	**D.** Designed and constructed microscopes, and was the first to observe unicellular microscopic organisms
e. Theodor Schwann	**E.** Proposed that all cells arise from cells that already exist
f. Rudolf Virchow	**F.** Used the term ‘cell’ to describe the tiny, box-like units in cork
g. Ernst Ruska	**G.** Used the term ‘nucleus’ to describe a structure found in plant cells

2. **Identify:**
   a. a feature that all living things have in common
   b. two units often used to describe the length of cells.

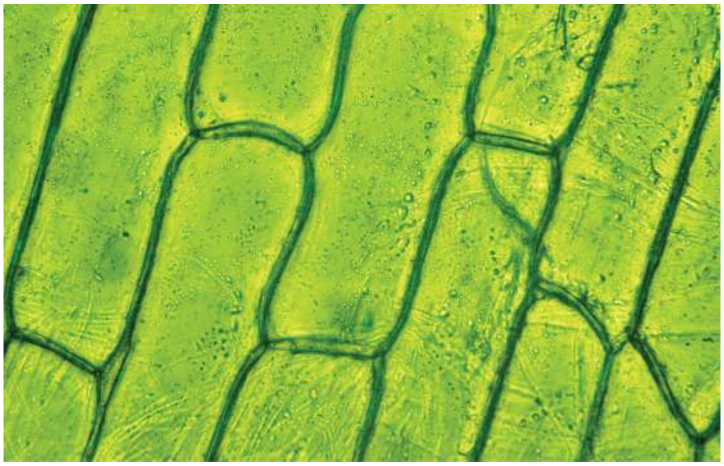
Apply and analyse

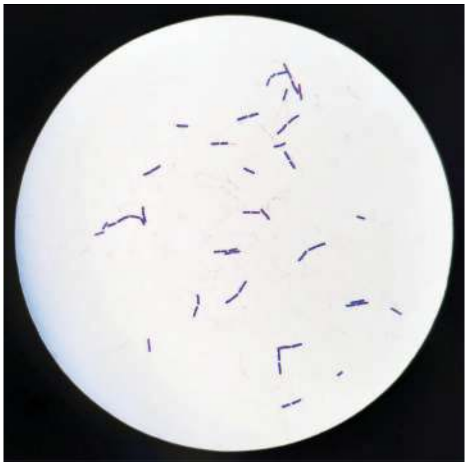
3. Use the timeline in figure 2.4 to answer the following questions.
   a. In which year did Hooke use the term ‘cells’ to describe his observation of cork slices?
   b. In which year did Ruska build the electron microscope?
   c. How many years were between:
      i. Hooke first using the term ‘cells’ and Ruska building the first electron microscope
      ii. Leeuwenhoek’s first observation of unicellular microscopic organisms and Schwann’s suggestion that all animals are made up of cells?
   d. Credit for developing the cell theory that ‘all living things are made up of one or more cells and that cells come from pre-existing cells’, is usually attributed to three scientists. **Name** them.
   e. **Suggest** how the development of the microscope has contributed to the understanding of cell structure.
   f. **Suggest** possible uses for portable microscopes.
4. Use figure 2.6 to complete the table.

Object	Size in nanometres (nm)	Size in micrometres (μm)	Size in millimetres (mm)
Frog egg			
Hair (width)			
Plant cell		100	
Bacteria		10	
Protein	10		

Evaluate and create

5. SI A student is presented with two slides, each showing different cells. The teacher asks the student to identify which cell is a bacterium and which cell belongs to a plant. They have access to a light microscope and the images are as follows.





   a. **Identify** a feature that could be used to distinguish between the different cells.
   b. Which cell do you think is the plant cell? **Explain** why you reached this conclusion.
   c. **State** what data should be collected as evidence to support your conclusion for part b.
6. SI To determine the average size of an elephant skin cell, two methods were suggested. These are outlined as follows:
   - Method 1 required ten Asian and ten African elephants to have one skin sample taken and measured to create an average using a light microscope.
   - Method 2 required one Asian and one African elephant to have ten skin samples taken and all of these were used to create the average. These would be measured using a range of light and electron microscopes.

a. In a table like the one provided, **compare** and **contrast** these two methods in terms of accuracy, reproducibility, repeatability, validity and fairness (fair test).

	Method 1	Method 2
Accuracy		
Reproducibility		
Repeatability		
Validity		
Fairness (fair test)		

b. **Construct** your own experimental design to determine the effect of elephant type on the average size of elephant skin cells. Remember to include the following:
  i. What is the independent variable; that is, what will change?
  ii. What are the controlled variables; that is, what will stay the same?
  iii. What is the dependent variable; that is, what will be measured?
  iv. How will the test be repeatable and reproducible?

Answers and sample responses are available in your digital formats.

LESSON 2.3 Focusing on a small world

LEARNING INTENTION

In this lesson you will:
- identify different types of microscopes and understand their specific purposes
- identify the key features of a microscope and describe how it works.

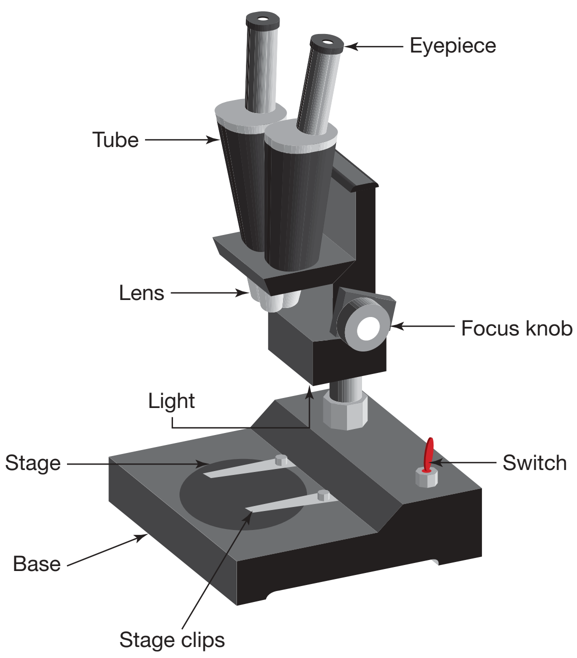
2.3.1 Types of microscopes

The two main types of microscopes are light microscopes and electron microscopes. **Light microscopes** use light rays, whereas **electron microscopes** use small particles called electrons to illuminate the specimen being viewed.

Light microscopes

You may have light microscopes at your school. These may be either **monocular microscopes** (using one eye) or **binocular microscopes** (using two eyes). It is important that the specimen you observe is very thin, so that the light can pass through it. However, one type of binocular microscope, a **stereo microscope**, allows you to see the detail of much larger specimens. Stereo microscopes can be used to observe various objects, including living organisms or parts of them.

FIGURE 2.8 Stereo light binocular microscope



Electron microscopes

Transmission electron microscopes (TEMs) show the internal structures of cells, whereas scanning electron microscopes (SEMs) show images of the surface features of the specimen. New electron microscope technologies are being developed, such as Ultrafast electron microscopy, which enables scientists to capture the movement of electrons, and a variety of three-dimensional microscopes that have exciting research and medical applications.

FIGURE 2.9 Scanning electron microscope

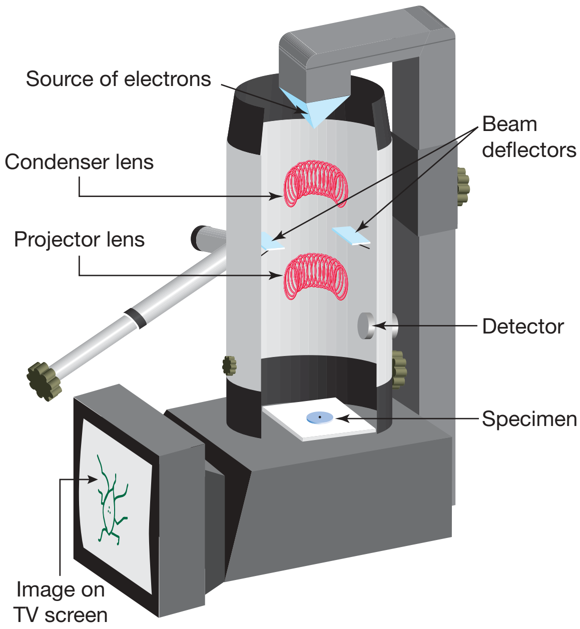


FIGURE 2.10 What's in your water? These images show zooplankton viewed through a scanning electron microscope. **a.** Chaetognath **b.** Daphnia **c.** A rotifer

Comparing microscopes

TABLE 2.2 Some comparisons between light microscopes and electron microscopes

Type of microscope	Magnification (how many times bigger)	Resolution (how much detail can be seen)	Advantage(s)	Disadvantage(s)	Examples of detail that can be seen
Light microscope	Up to × 2000	Up to about 500 times better than the human eye	Samples prepared quickly; coloured stains can be used; living cells can be viewed	Limited visible detail	Shapes of cells; some structures inside cells, e.g. nucleus and chloroplasts
Electron microscope	Up to × 2 000 000	Up to about 5 million times better than the human eye	High magnification and resolution	Only dead sections can be viewed; specimen preparation is difficult; very expensive	All parts of cells; viruses

2.3.2 Magnification

The two lenses that determine the **magnification** of your microscope are the eyepiece lens and the objective lens. Each lens has a number on it that signifies its magnification. Multiplying the eyepiece number by the objective lens number will give you the magnification of the microscope. For example:

- eyepiece lens (ocular) magnification = ×10
- objective lens magnification = ×40
- total magnification of the microscope = ×400.

FIGURE 2.11 As the field of view gets smaller, the magnification gets larger.

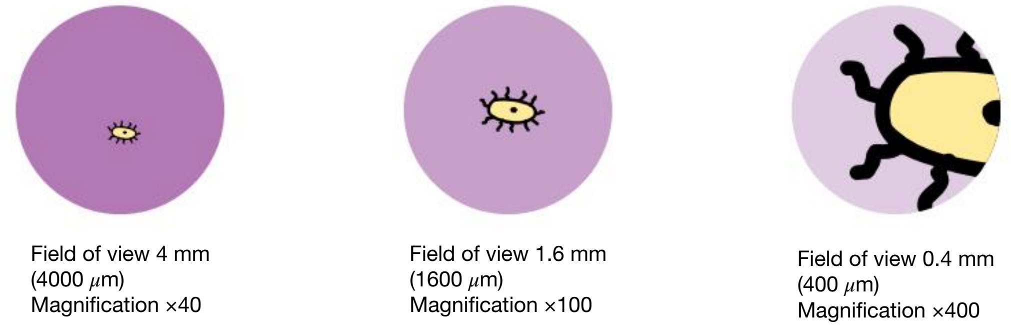
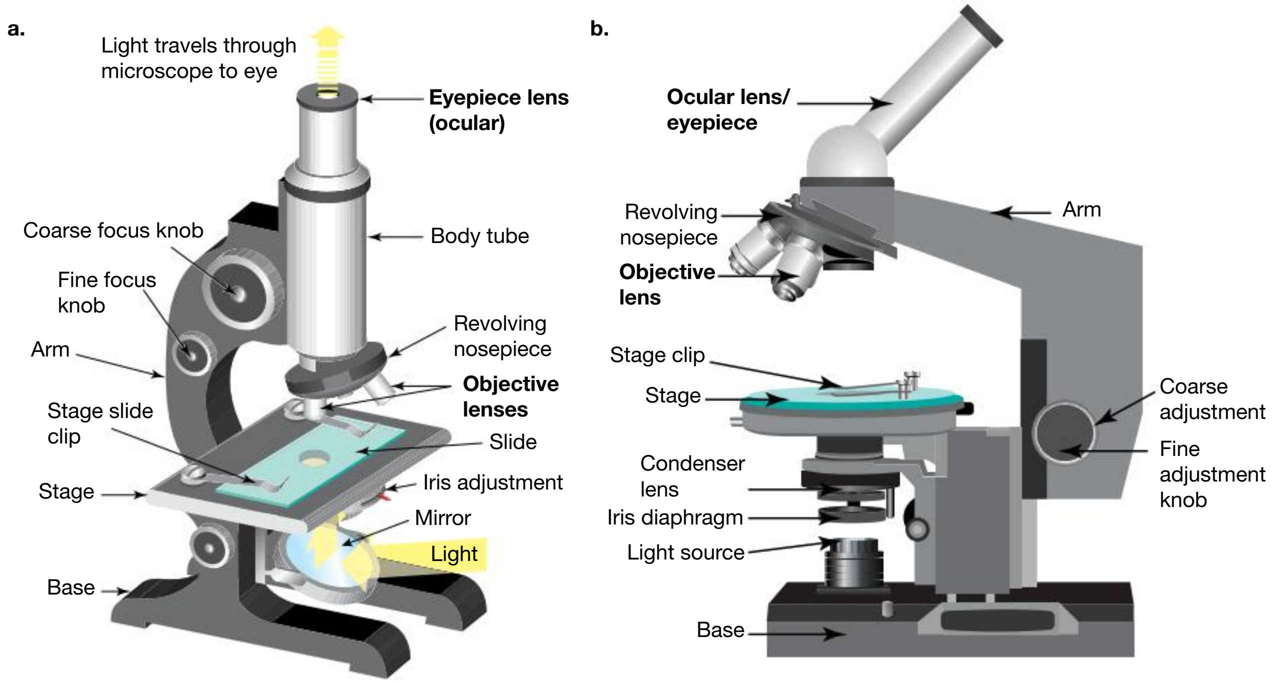


FIGURE 2.12 a. The monocular light microscope **b.** Light microscope with built-in light



KEY IDEA

Microscope handling and maintenance guidelines

1. When lifting the microscope, put one hand on the arm of the microscope and one hand under its base.
2. The microscope should be used on a flat surface with the arm closest to you, and not too close to the edge.
3. Take care that the light intensity is not too high, or it might damage your eye.
4. Always begin with the shortest (lowest power) objective lens.

5. When you have finished using the microscope, return the shortest objective lens into position.
6. Remove the slide, and ensure that the stage is clean.
7. Make sure that when your microscope is not in use, it is always clean and carefully put away.

Using a microscope

1. Adjust your mirror so the appropriate amount of light passes through the hole in the stage.
2. Place the glass microscope slide (with a single hair specimen on top) onto the stage.
3. While watching from the side, use the coarse focus knob to adjust the objective lens or stage, until they are just apart, or just above the slide. Moving it too close may shatter the slide.
4. While looking through the eyepiece lens, carefully turn the coarse focus knob to lower the stage, moving the stage and objective lens apart until the specimen is seen clearly.
5. Carefully use the fine focus knob so that you can see the details of your specimen as clearly as possible. Each time you change the objective lens, adjust only with the fine focus knob.
6. Sketch what you see.
7. Suggest the number of times your specimen has been magnified by.

FIGURE 2.13 How to focus your microscope, step 3

INVESTIGATION 2.1

Getting into focus with an 'e'

Aim

To practise focusing a monocular light microscope

Materials

- 1 cm square piece of newsprint containing the letter 'e'
- monocular light microscope
- microscope slide
- clear sticky tape

Method

1. Carefully stick the 1 cm square of newsprint onto a clean microscope slide using sticky tape.
2. Using the microscope directions, get the paper into focus using the coarse focus knob and the lowest power objective lens (smallest magnification).
3. Carefully move the slide until you have a letter 'e' in focus.
4. Change to a higher level of magnification by rotating to a higher power objective lens.
5. Draw a sketch of what you see under ×100 or ×400 magnification in the results section. Remember not to shade the image, outline only.
6. Record how many 'e's would fit across the field of view. Use this to estimate the size of the 'e' by dividing the size of the field of view by the number of 'e's that would fit across the field of view.
7. Move the slide towards you. Record which direction the 'e' moves.
8. Move the slide to the left. Record which direction the 'e' moves.

Results

1. Under the microscope, how did the paper appear to move when you shifted the slide (a) towards you and (b) to the left?

2. Observe and illustrate the appearance of the letter ‘e’ under the microscope. Use a pencil to create a detailed sketch of what you see.
3. Record the magnification that you use and estimate how much of the viewed area is covered by the letter ‘e’ at this magnification.

Discussion

1. Analyse how changing the magnification affected the amount of detail visible on the letter ‘e’.
2. What occurred when the slide was moved (a) towards you and (b) to the left? Can you suggest a reason for this? (*Hint*: Look at how a light microscope works.)
3. Suggest what the letters ‘P’ and ‘R’ would look like under the microscope.
4. Propose a research question that you could explore using a light microscope, and describe how you could investigate it.

Conclusion

Summarise the findings for this investigation.

INVESTIGATION 2.2

Can you tell the difference?

Aim

To explore and observe various specimens with a monocular light microscope, identifying their similarities and differences

Materials

- monocular light microscope
- microscope slides
- clear sticky tape
- hair strands (from different individuals)
- spatula
- selection of white powders and crystals (e.g. flour, salt, sugar, baking soda)
- different brands or types of spices and leaf tea
- fibres (e.g. cotton, linen, silk, wool, nylon)

Method

Fibres

1. Remove a fibre strand from one of the materials and stick it on a clean microscope slide using sticky tape.
2. Using the microscope directions, get the fibre into focus using the coarse focus knob and the lowest power objective lens (smallest magnification). Sketch what you see.
3. Change to a higher level of magnification by rotating to a higher power objective lens.
4. Draw a sketch of what you see with each magnification in the results section. Remember not to shade the image, outline only.
5. Repeat steps 1–4 for fibres from other materials.

Powders

6. Using a spatula, stick a tiny amount of flour on a clean microscope slide with sticky tape (make sure it is a very thin layer).
7. Using the microscope directions, get the powder into focus using the coarse focus knob and the lowest power objective lens (smallest magnification). Sketch what you see.
8. Change to a higher level of magnification by rotating to a higher power objective lens.
9. Draw a sketch of what you see with each magnification in the results section. Remember not to shade the image, outline only.
10. Repeat steps 6–9 for other powders and/or spices and leaf tea.

Results

Sketch the specimens viewed. Include detailed descriptions, the magnification used and an estimate of size next to your diagrams.

Discussion

1. Analyse how adjusting the magnification impacted the level of detail visible in the different specimens.
2. Identify ways in which the different specimens were similar and ways in which they were different.

Conclusion

Summarise the findings for this investigation.

2.3.3 Award-winning images

Microscopes are not just used to observe images of organisms. They are also used in many other areas of science. Some microscope images win awards recognising not just expertise but also creativity. For example, the Nikon Small World Photomicrography Competition invites photographers and scientists to submit images of all things visible under a microscope. The following figures show examples of some of the 2022 winners.

FIGURE 2.14 The 2022 first place image of the embryonic hand of a Madagascar giant day gecko

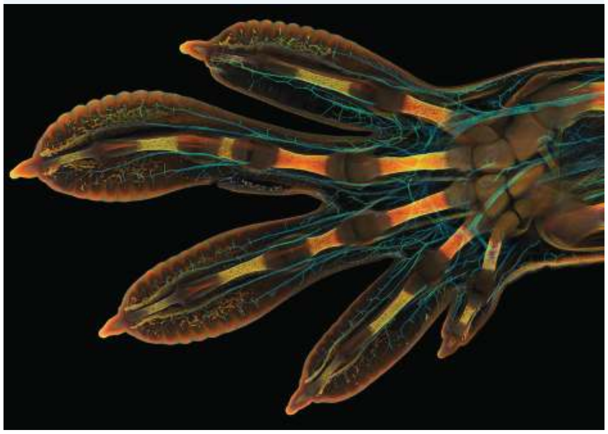


FIGURE 2.15 Tiny, finger-like villi found in the small intestines

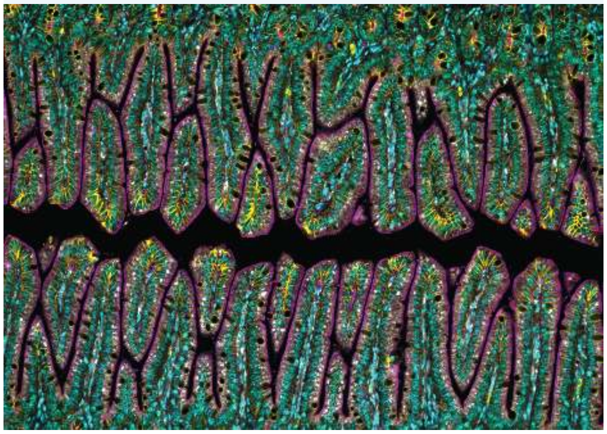


FIGURE 2.16 A cross-section of a white asparagus shoot tip

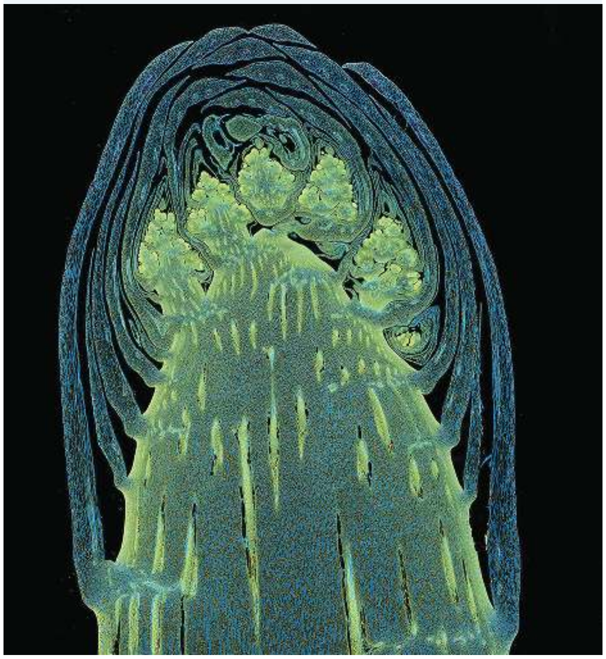


FIGURE 2.17 A single coral polyp (measuring approximately 1 mm)

ACTIVITY: Understanding microscopes and their key features

Microscopes are one of the most important tools in science, allowing you to see objects too small to observe with the naked eye. Over time, different types of microscopes have been invented, each with its specific purpose and features.

As a class, discuss the following questions.

1. How did the invention of the microscope change the way scientists studied life?
2. Why was the electron microscope such an important breakthrough for understanding cells?
3. What new discoveries about cells might be made with even more advanced technology?

2.3 Activities

learnon

2.3 Quick quiz on | 2.3 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 10, 12, 13	3, 7, 8, 9, 14	4, 5, 6, 11, 15

Remember and understand

1. a. **Identify** whether the following statements are true or false.

Statement	True or false?
i. A light microscope can produce a greater magnification than an electron microscope.	
ii. Only dead sections can be viewed on an electron microscope.	
iii. Viruses can be viewed on a light microscope.	
iv. Resolution refers to how many times bigger a specimen is, whereas magnification refers to how much detail you can see.	
v. More detail can be seen in thicker specimens when using a monocular light microscope.	

   b. Rewrite any false statements to make them true.
2. **Suggest** why it is important not to have the light intensity setting too high on a light microscope.
3. Determine what happens to the magnification as the field of view of your microscope decreases.
4. Observe and **describe** what occurs when you move the microscope slide while looking through the microscope.
   a. To the left
   b. To the right
   c. Towards you
   d. Away from you

Apply and analyse

5. **Explain** the importance of watching from the side of the microscope while using the coarse focus knob.
6. Use figure 2.11 to answer the following questions. (*Note*: 1000 μm = 1 mm)
   a. Estimate the length of the specimen shown in the diagram at ×40, ×100 and ×400 magnification.
   b. **Describe** the differences in your observations of the three different magnifications.
7. **Construct** Venn diagrams to distinguish between:
   a. a monocular microscope and a stereo microscope
   b. a light microscope and an electron microscope

c. a transmission electron microscope and a scanning electron microscope
d. resolution and magnification
e. field of view and magnification.

8. If a specimen is 1 mm in length, how big will it appear if it is magnified ×100?
9. If a specimen takes up the entire field of view at ×100, how much of it will be seen at ×400?
10. Sketch a line diagram or take a photo of your microscope and label as many of its parts as you can, using figure 2.12.
11. Copy and complete the table provided.

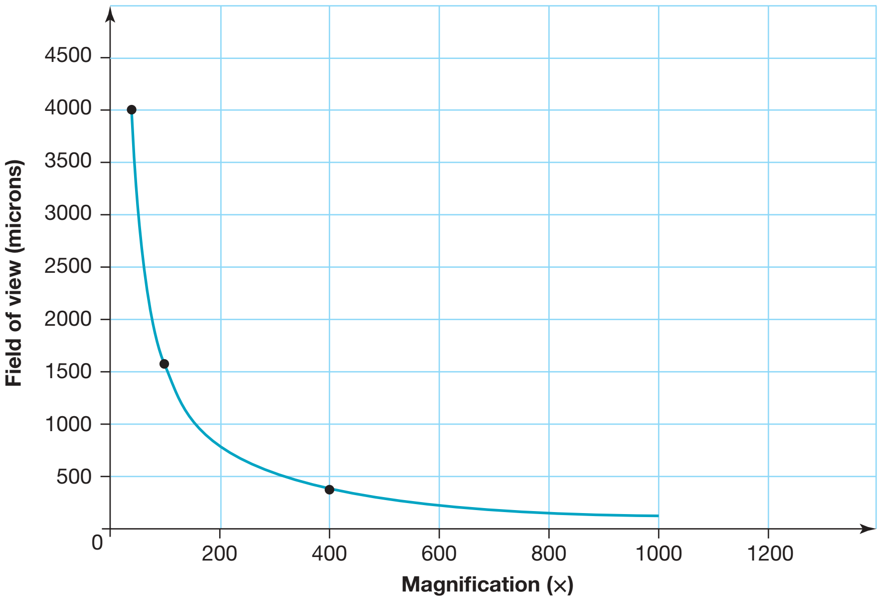
Ocular lens (eyepiece)	Objective lens	Magnification
×5	×5	×25
×5	×10	
×10		×100
	×40	×400

12. Match the part of the microscope with its function.

Part	Function
a. Objective lens	A. Where the slide is placed
b. Slide	B. Thin piece of glass where the specimen is placed
c. Stage clip slide	C. Magnifies the image
d. Iris adjustment	D. Allows large adjustments to the distance between the stage and objective lens, which helps bring images into focus
e. Coarse focus knob	E. Adjusts the amount of light reaching the eyepiece
f. Stage	F. Allows small adjustments to the distance between the stage and the objective lens, which helps bring the image into closer focus
g. Fine focus knob	G. Holds the slide in place

Evaluate and create

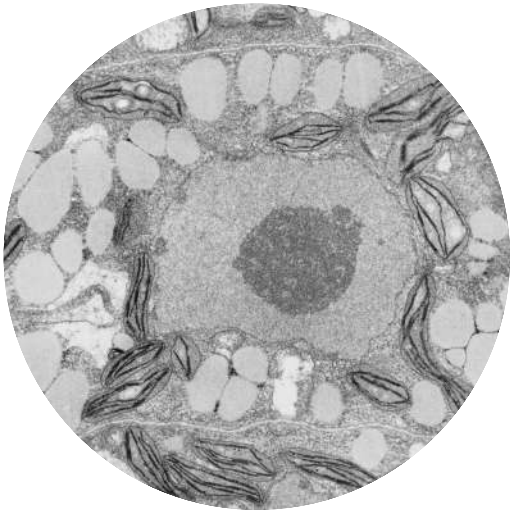
13. Create a poster that shows either how a microscope should be used or what happens when you use it the wrong way.
14. SI This graph shows how the field of view changes with magnification under a light microscope.



a. The graph is missing a title. **Suggest** a title.
b. Some light microscopes have an additional objective lens called an oil immersion lens. This can magnify ×100.
   i. Assuming the eyepiece is ×10, **state** the total magnification if you were using this lens.
   ii. Use the graph to determine how big the field of view would be.
c. The oil immersion lens increases resolution. **Explain** what the term *resolution* means.

15. SI **State** which of the following plant cell images, a or b, is taken with a light microscope, and which is taken with an electron microscope. Use evidence from the images to **justify** your conclusion.

a.



b.

Answers and sample responses are available in your digital formats.

LESSON 2.4 Form and function — cell make-up

LEARNING INTENTION

In this lesson you will:
- recognise that organisms consist of a single cell or multiple cells
- identify key organelles within cells and describe their function.

2.4.1 Similar, but different

Cells are the building blocks that make up all living things. Organisms may be made up of one cell (unicellular) or many cells (multicellular). These cells contain small structures called **organelles** that have particular jobs within the cell and function together to keep the organism alive.

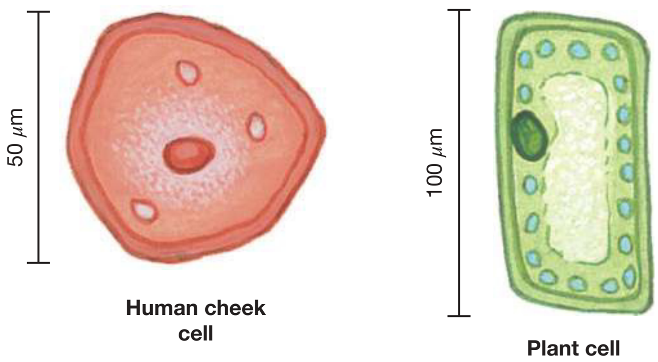
Cells can be categorised on the basis of the presence and absence of particular organelles and other structural differences. Organisms can be classified by the different types of cells they are made up of.

How big is small?

The size of cells may vary between organisms and within a multicellular organism. Most cells are too small to be seen without a microscope. Cells need to be very small because they have to be able to quickly take in substances they need and remove wastes and other substances (figure 2.18). The bigger a cell is, the longer this process would take.

Very small units of measurement are used to describe the size of cells. The most commonly used unit is the micrometre (μm). One micrometre equals one millionth (1/1 000 000) of a metre or one thousandth (1/1000) of a millimetre. Check out your ruler to get an idea of how small this is! Most cells are in the range of 1 μm (bacteria) to 100 μm (plant cells).

FIGURE 2.18 The most commonly used unit is the micrometre (μm).



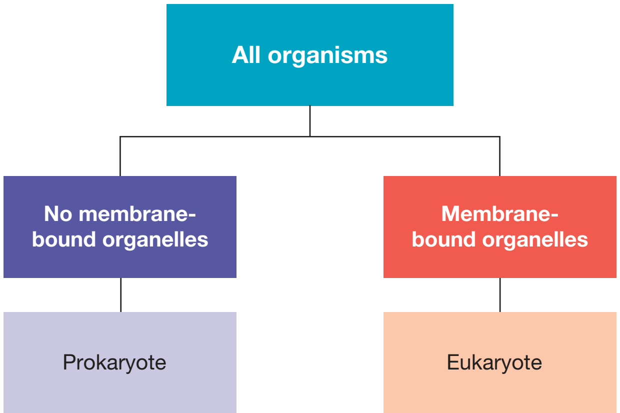
Advances in technology are creating an increased need for the use of the **nanometre** (nm) as a unit. One nanometre equals 1 billionth (1/1 000 000 000) of a metre. Investigating the organelles within cells and the molecules they react with requires this level of measurement.

Nanotechnology is a rapidly developing field that includes studying and investigating cells at this ‘nano level’. While it requires lots of creative, exciting and futuristic ‘what if’ thinking, it also involves an understanding of the basics of information and ideas that are currently known.

2.4.2 Have it or not?

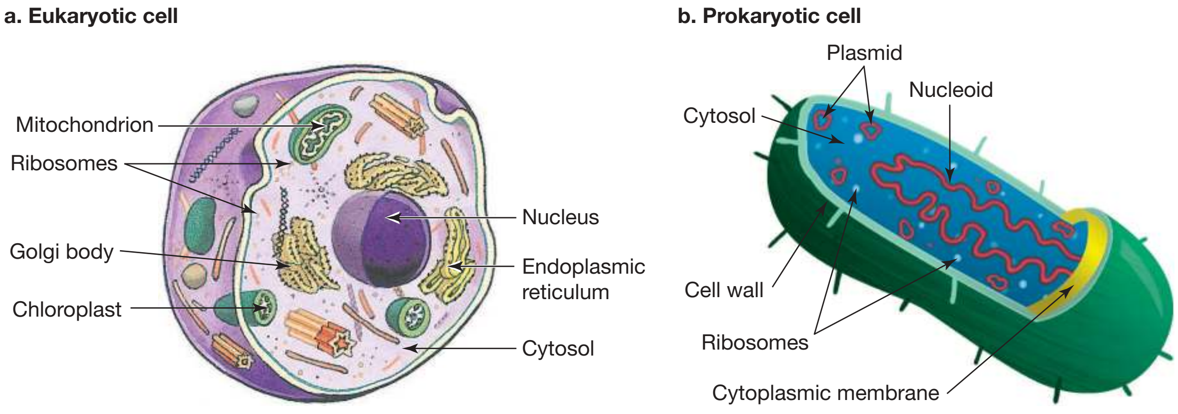
Prokaryotes such as bacteria were the first type of organism to appear on Earth. The key difference between prokaryotes and all other kingdoms is that members of this group do not contain a nucleus or other membrane-bound organelles. The word prokaryote comes from the Greek terms *pro*, meaning ‘before’, and *karyon*, meaning ‘nut, kernel or fruit stone’, referring to the cell nucleus.

FIGURE 2.19 Prokaryotes and eukaryotes



Eukaryotic organisms made up of eukaryotic cells appeared on Earth billions of years later. As *eu* is the Greek term meaning 'good' or 'true', **eukaryote** can be translated as 'true nucleus'. Members of the kingdoms Animalia, Plantae, Fungi and Protista are eukaryotes, and are made up of cells containing a nucleus and other membrane-bound organelles.

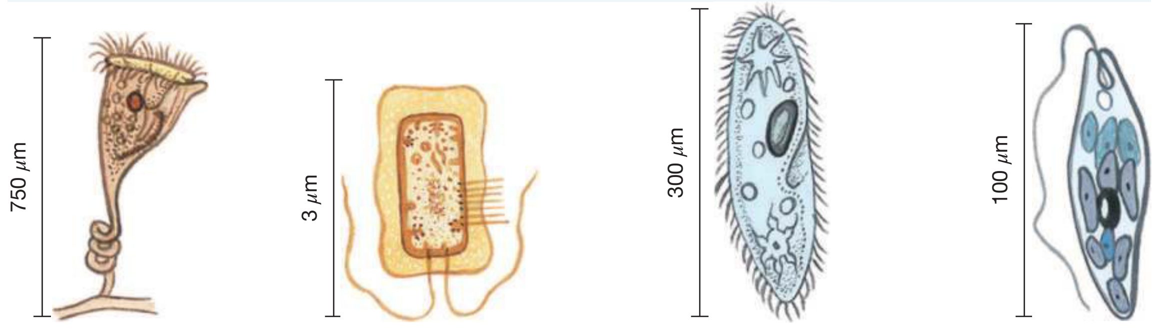
FIGURE 2.20 Eukaryotic cells **a.** contain a nucleus and membrane-bound organelles, whereas **b.** prokaryotic cells do not.



2.4.3 What do we share?

What most cells have in common is that they are made up of a **cell membrane** containing a fluid called **cytosol** and small structures called **ribosomes**. The collective term used to describe the cytosol and all the organelles suspended within it is **cytoplasm**. The hundreds of chemical reactions essential for life that occur within the cytoplasm are referred to as the cell's **metabolism**. The ribosomes are where proteins such as enzymes, which regulate the many chemical reactions important to life, are made. The cell membrane regulates the movement of substances into and out of the cell. This enables the delivery of nutrients and substances essential for reactions, and the removal of wastes.

FIGURE 2.21 Different sizes



Vorticella

Bacterium

A *Paramecium* is a unicellular protist (or protoctistan).

Euglena

DISCUSSION

1. What are some advantages and disadvantages of being unicellular versus multicellular?
2. How do unicellular organisms, such as bacteria, survive with only one cell?

2.4.4 Designed for optimum function

Regardless of whether an organism is unicellular or multicellular, all cells have a job to do.

In unicellular cells such as bacteria and some protists such as amoeba, *Euglena* or *Paramecium*, the cell is designed to meet all of the organism's needs — gaining nutrients, expelling wastes and reproducing by producing an exact replica of the parent cell.

What nutrients do you think cells need? What waste products do you think cells produce? Why is it important that these waste products are expelled?

Multicellular organisms have certain cells that carry out certain functions. A group of these cells creates **tissue** that has particular components that specialise it for its function. An organ is a collection of tissues joined together. These organs are part of a system that has a specialised role; for example, the digestive system or the skeletal system.

FIGURE 2.22 Unicellular organisms

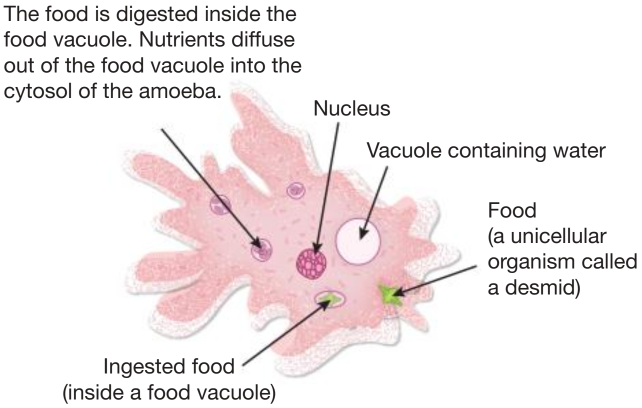
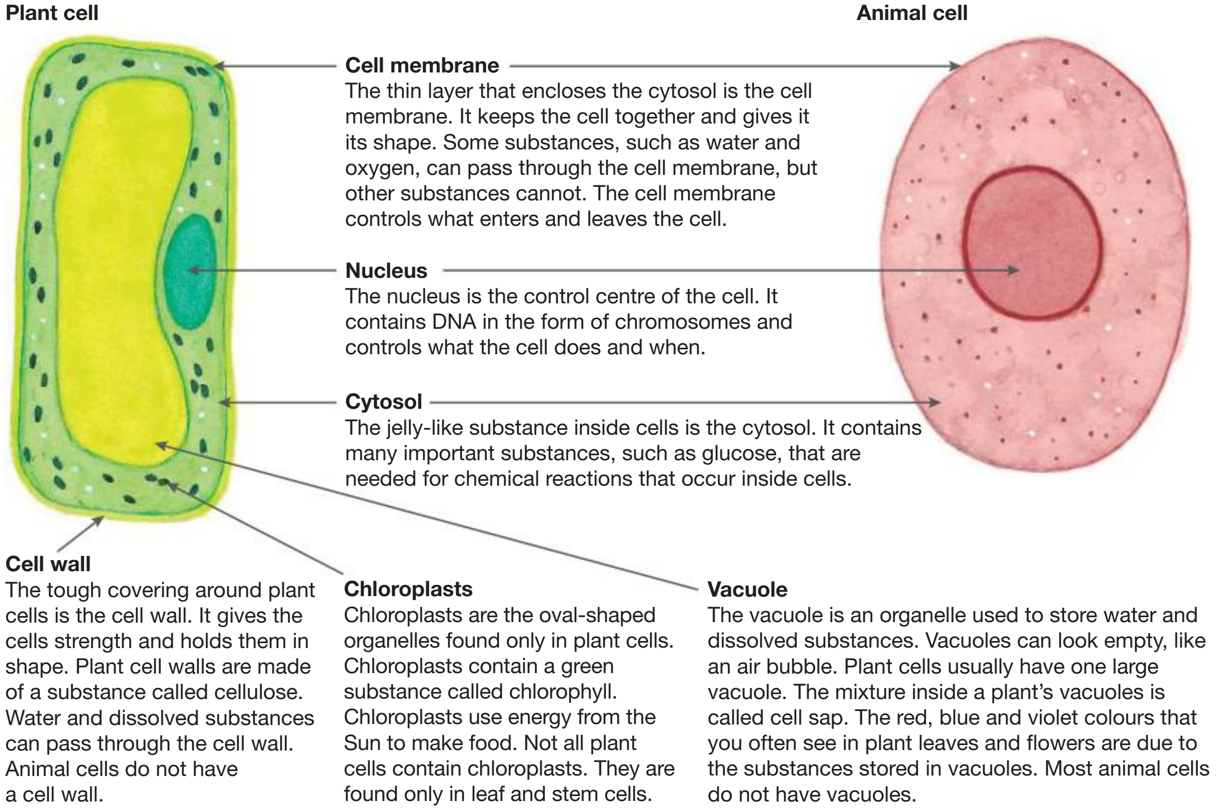


FIGURE 2.23 Different types of cells have particular structures enabling specialised tasks.



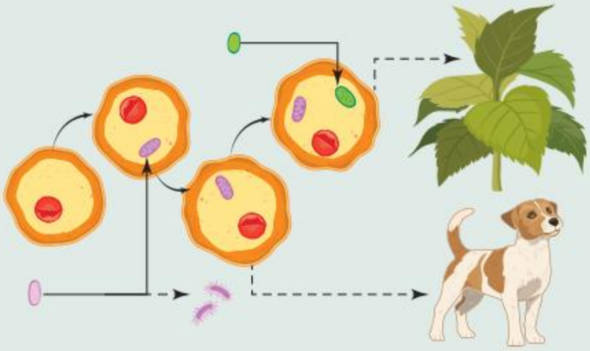
Microfactories

Mitochondria and **chloroplasts** are examples of membrane-bound organelles found in eukaryotic cells. While all eukaryotic cells contain mitochondria, because they are all involved in **cellular respiration**, only those involved in **photosynthesis** (such as those in plant leaves) contain chloroplasts. Chloroplasts contain the green pigment **chlorophyll**. This pigment is used to trap light energy so that it can be converted into chemical energy and used by the cells.

EXTENSION: The endosymbiotic theory

The endosymbiotic theory suggests that mitochondria and chloroplasts were once prokaryotic organisms. This theory proposes that, at some time in the past, these organisms were engulfed by another cell and over time they evolved to depend on each other.

FIGURE 2.24 The origin of the eukaryotic cell? Some scientists also suggest that our nucleus may have come from a giant viral ancestor.



SCIENCE INQUIRY: Developing investigable questions and hypotheses about cells

Scientists often begin their investigations into cells by asking questions based on observations. For example, why do muscle cells contain more mitochondria than skin cells? Why do plant cells have cell walls, but animal cells do not? These questions are the foundation of scientific inquiry, guiding investigations to better understand cell structure and function.

From these questions, scientists form reasoned predictions and hypotheses. As you have learnt previously, a hypothesis is an educated guess about the relationship between variables, based on prior knowledge. For example, a hypothesis might be: 'Cells that require more energy will have a higher number of mitochondria.' This hypothesis can then be tested by examining various cell types under a microscope and counting their mitochondria.

Investigations might also explore relationships, such as the link between cell size and its ability to perform specific functions. For example, scientists might ask: 'Does a larger cell size mean the cell can store more nutrients or produce more energy?' These types of questions help researchers identify patterns and connections between a cell's structure and its job in the organism.

Developing meaningful questions and hypotheses is a crucial step in guiding investigations that advance our understanding of cells.

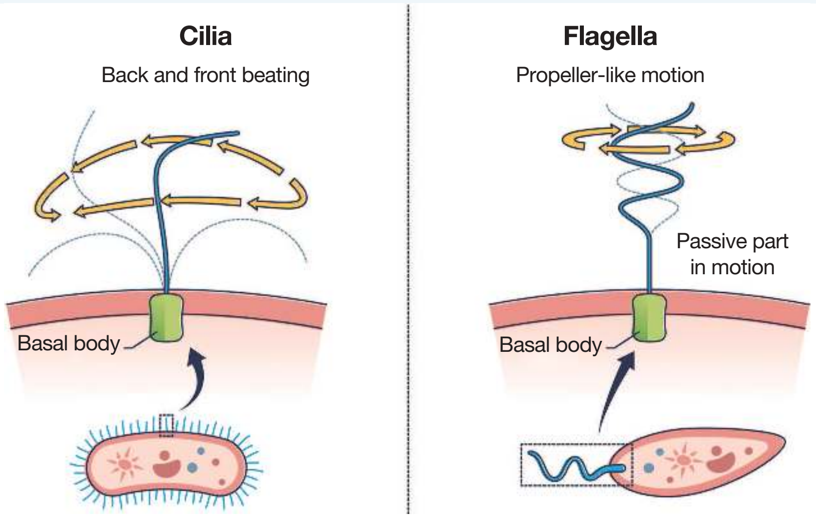
1. How does the number of mitochondria in a cell relate to the energy demands of its function?
2. Why might vacuoles in plant cells be larger than those in animal cells?
3. What role does cell size play in nutrient absorption or energy production?

Investigable questions, reasoned predictions, and hypotheses can be developed in guiding investigations to identify patterns, test relationships, and analyse and evaluate scientific models (VC2S8I01)

External structures

Specialised external structures such as cilia and flagella may also be a feature of a cell to assist with its movement in the organism.

FIGURE 2.25 The structure and motion of cilia and flagella



2.4.5 Differences in the basic cell design between eukaryotic and prokaryotic cells

Eukaryotic and prokaryotic cells have important differences in how they are built and how they work. These differences can be seen in the six main groups of living things. Table 2.3 shows how these cell types compare.

TABLE 2.3 Differences in the basic cell design in the six kingdoms

	Eukaryotic				Prokaryotic	
Characteristic	**Animalia** (animals; e.g. lizards, fish, spiders, earthworms, sponges)	**Fungi** (e.g. yeasts, moulds, mushrooms, toadstools)	**Plantae** (plants; e.g. ferns, mosses, conifers, flowering plants)	**Protista** (e.g. algae, protozoans)	**Eubacteria** (bacteria and cyanobacteria)	**Archaebacteria**
Number of cells	Multicellular	Usually multicellular but some unicellular	Most multicellular	Unicellular or multicellular	Unicellular	Unicellular
Nucleus	✓	✓	✓	✓	X	X
Cell wall	X	✓	✓	Present in some	✓	✓
Large vacuole	X	X	✓	Present in some	X	X
Chloroplasts	X	X	Present in leaves and stem cells	Present in some	Absent (but chlorophyll may be present in some)	X

2.4 Activities

learnon

2.4 Quick quiz on	2.4 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 8, 12	2, 3, 6, 10	5, 7, 9, 11

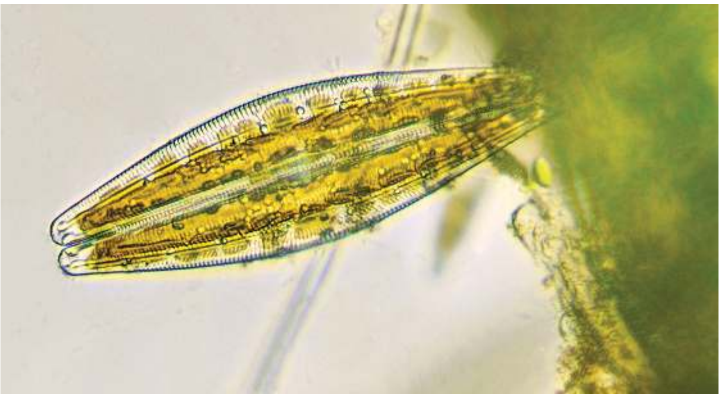
Remember and understand

1. **State** why the nucleus is important to the cell.
2. **Identify** where enzymes are made in a cell and state why they are important.
3. SI Emily is trying to determine if increasing the temperature of an enzyme will increase the reaction rate. She uses an enzyme that breaks down the starch in potato into sugar. She sets up three beakers. The first has 10 g of potato in 200 mL of water at 20 °C (room temperature). The second beaker has 10 g of potato in 200 mL of water and 5 g of the enzyme at 20 °C. The third beaker has 10 g of potato in 200 mL of water and 5 g of the enzyme heated to 30 °C. She measures the amount of glucose at the end of 10 minutes.
   a. **Identify** the independent and dependent variables.
   b. Is a control group used in this experiment? If so, **state** which beaker it is.
   c. Is this experiment a fair test? **Explain** using the definition of fair test.
4. Complete the table by identifying which kingdoms relate to the characteristics.

Characteristics	Kingdom
Does not have a cell wall, large vacuole or chloroplasts	
Has a cell wall, large vacuole and chloroplasts	
Has a cell wall, but no large vacuole or chloroplasts	
Has a cell wall and cell membrane but no nucleus	

Apply and analyse

5. **Analyse** how the structure of specialised cells, such as nerve or muscle cells, supports their specific functions in the body.
6. SI Look at the image and answer the following questions.
   a. **Identify** the features you can observe in the cell.
   b. Hypothesise which kingdom this cell belongs to.
   c. Can a hypothesis be incorrect? **Explain** your answer.



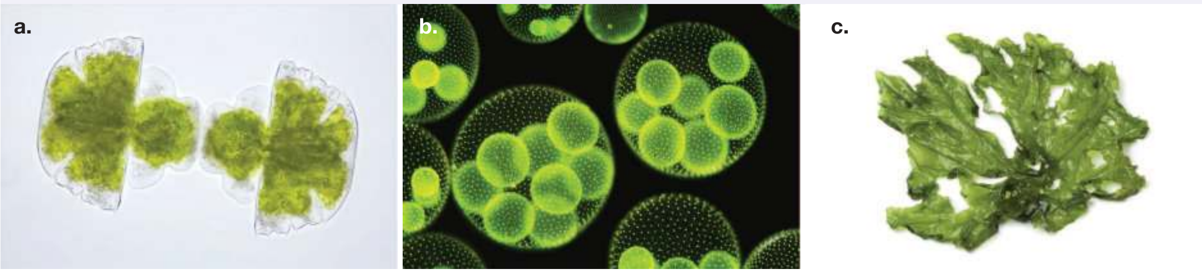
7. **Analyse** the advantages and disadvantages of being a unicellular organism versus a multicellular organism. Consider aspects such as survival, reproduction and adaptation to different environments.

Evaluate and create

8. **Construct** a labelled 2D or 3D model of a cell from one of the kingdoms and explain how the representation models the cell. Use materials available at home, such as drink bottles, egg cartons, cottonwool, wool, cotton or dry foods.
9. SI Algae have many different forms. Broadly, they can be broken into three groups:
   - Green algae
   - Brown algae
   - Red algae.

   Green algae are a group of 9000–12 000 species. They all have a central vacuole and chloroplasts, and some forms have flagella, making them motile (able to move). They can be unicellular, form colonies or be multicellular.

   a. Desmid — a unicellular green algae **b.** *Volvox* — a colony formed of unicellular algae **c.** Sea lettuce — a multicellular green algae

   Brown algae are a large group of multicellular algae, including many seaweeds. They have chloroplasts surrounded by four membranes (compared to the usual two). Some also possess flagella.

   Red algae are a group of approximately 7000 species that have a lifecycle much like that of a fungus. They have no flagella and so they are non-motile. They are mainly multicellular but there are some that are unicellular. They contain chloroplasts.

   All algae have cell walls that contain cellulose. There is much discussion over which kingdom the algae should belong to and whether or not the three divisions should be grouped together. Which kingdom do you think the algae should belong to? **Justify** your response using evidence from the information given.

   Harpoon weed red algae (*Asparagopsis armata*) underwater in the Mediterranean Sea, Spain

10. **Evaluate** the importance of each key organelle within a cell. Discuss how the malfunction of one organelle could impact the overall function and health of the cell.
11. **Compare** the cellular structures of different types of organisms, such as bacteria, plants and animals. Explain how these structures are adapted to their specific functions and environments.
12. **Assess** the role of cell specialisation in multicellular organisms. How does the differentiation of cells contribute to the overall functioning and efficiency of the organism?

Answers and sample responses are available in your digital formats.

LESSON 2.5 Zooming in on life

LEARNING INTENTION

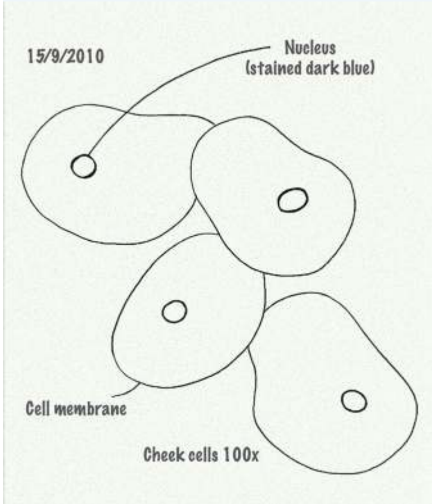
In this lesson you will:
- understand how to prepare a specimen for viewing with a microscope, including the use of dyes to highlight specific cell features
- record images using scientific drawing techniques.

2.5.1 Sketching what you see under the microscope

Some points to remember

1. Use a sharp pencil.
2. Draw only the lines that you see (no shading or colouring).
3. Your diagrams should take up about a third to half of a page each.
4. Record the magnification next to each diagram.
5. State the name of the specimen and the date of observation.
6. A written description is also often of considerable value.
7. When you are viewing many cells at one time, it is often useful to select and draw only two or three representative cells for each observation.

FIGURE 2.26 An example of a sketch of a microscope specimen



2.5.2 Preparing a specimen

Light microscopes function by allowing light to pass through the specimen to reach your eye. If the specimen is too thick, the object cannot be seen as clearly or may not be seen at all.

Careful peeling, scraping, slicing or squashing techniques can be used to obtain thin specimens of the object to be studied.

Staining a specimen

Many objects are colourless when viewed under the microscope, so specimens are often treated with stains, which are types of dyes, to enhance their visibility. Commonly used dyes include methylene blue, iodine and eosin, which act as stains to highlight specific cell features.

Each stain reacts with different chemicals in the specimen. For example, iodine stains starch a blue-black colour.

Take care when using these dyes, because they can stain your skin and clothes as well!

INVESTIGATION 2.3

Preparing a wet mount

Aim

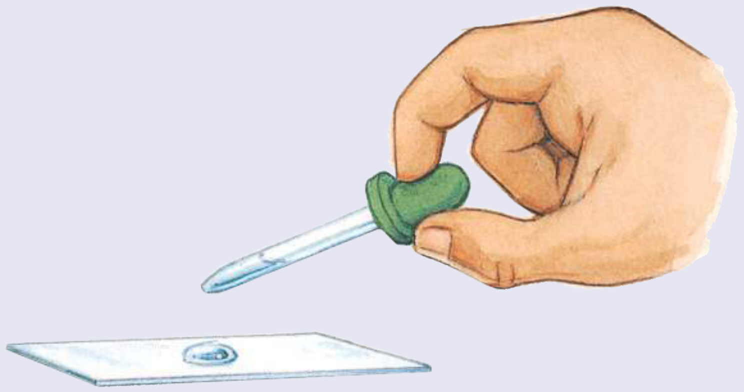
To prepare a wet mount slide and use a microscope to observe and identify microorganisms in a pond water sample

Materials

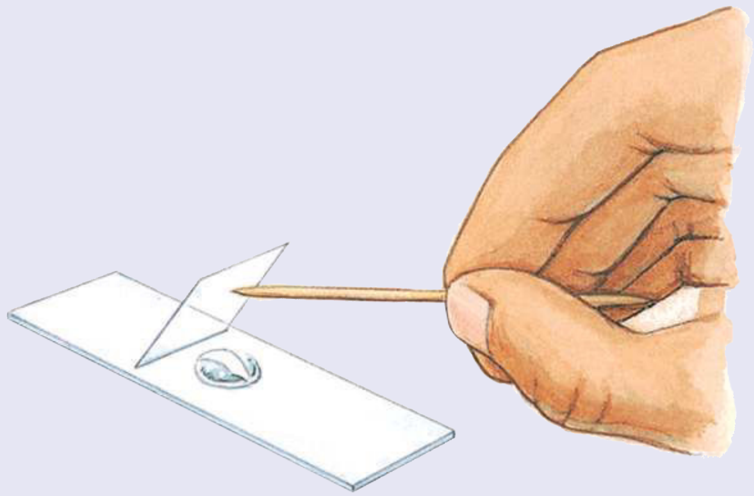
- light microscope
- coverslips
- pipette
- toothpick
- pond water
- microscope slides (well slides work best for this)
- culture of living microscopic organisms: *Paramecium*, amoeba, rotifers, *Euglena*

Method

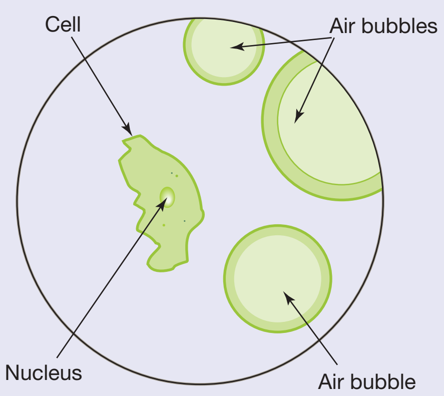
1. Use the pipette to put a drop of pond water or microbe culture on a clean microscope slide.



2. Gently place a coverslip over the drop of water by putting one edge down first. Use a toothpick as shown.
3. Incorrect placement of the coverslip can result in air bubbles.



4. Use a microscope to observe the slide.



5. Once you have recorded your results, remove the coverslip, rinse and dry the slide, and then prepare a new slide specimen and repeat the steps above.

Results

Draw detailed sketches of what you see. Remember to include a title, the magnifications used and as many observations about the specimen as you can.

Discussion

1. Construct a matrix to compare the similarities and differences between the observed specimens using the table provided.

	Plants	Algae	Creatures
Stationary			
Flagellum			
Fast moving			

2. Suggest reasons for these differences.
3. Investigate using online resources to identify the specimens you observed.
4. Which kingdoms do you think each specimen may belong to? Provide reasons for your classification.
5. Identify two physical structures observed during the investigation and explain their functions (what they do or their specific roles in the organism).
6. You have been observing living specimens. Identify the advantages and disadvantages of using living rather than dead specimens or prepared slides.

Conclusion

Summarise the findings for this investigation.

INVESTIGATION 2.4

Preparing stained wet mounts

Aim

To prepare and stain a microscope slide to observe the cellular structures of a specimen

Materials

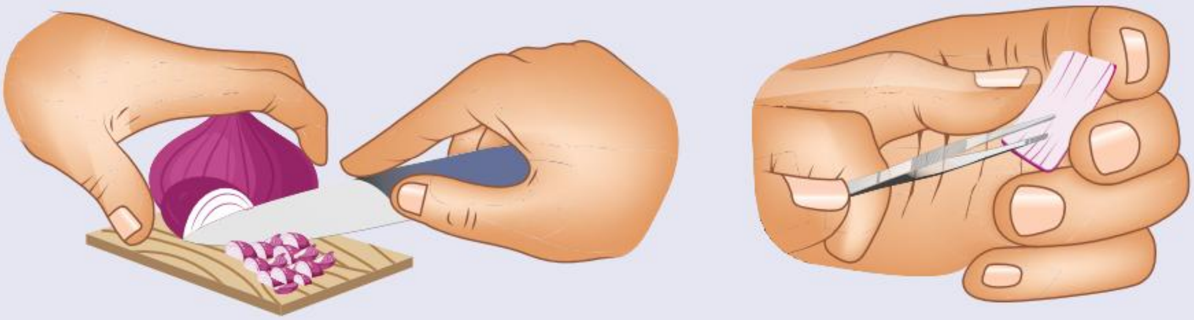
- light microscope
- pipette
- blotting paper
- toothpick
- scalpel
- forceps or tweezers
- microscope slides and coverslips
- water, methylene blue, iodine
- onion, ripe and unripe banana, celery stick, potato

CAUTION: The scalpel has a very sharp blade. Handle it with care.

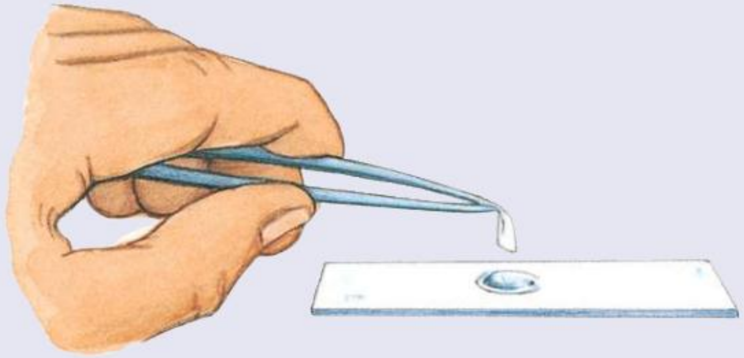
Method

1. Use the pipette to put a drop of water on a clean microscope slide.

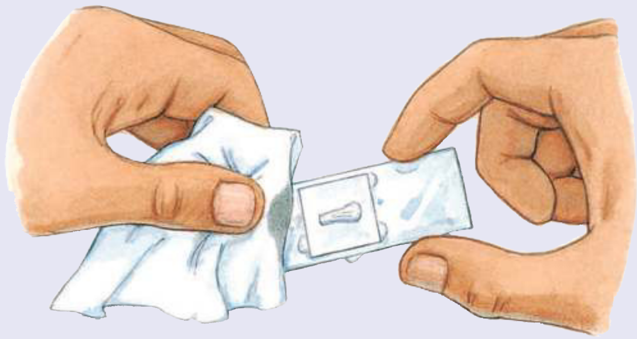
2. Use a scalpel and forceps to peel a small piece of the very thin, almost transparent onion skin from the inside surface of an onion. You may also be able to snap the piece of onion and peel a thin layer of skin off.



3. Use the forceps to put the thin piece of the onion skin into the drop of water on the microscope slide.



4. Gently place a coverslip over the drop of water containing the onion skin by putting one edge down first. Use a toothpick as in investigation 2.3 to avoid air bubbles. Use blotting paper to soak up any excess water outside the coverslip.



5. Use a microscope to observe the slide; first use low power and then increase the magnification.
6. Prepare another slide of onion skin, except this time add a drop of methylene blue instead of water to the slide. Make sure that you carefully blot excess stain from the slide after you add the coverslip.
7. Observe this stained onion specimen; first use low power, then view at a higher magnification.

Once you have recorded your results:

8. Remove the coverslip, and rinse and dry the slide.
9. Use the previously outlined steps to prepare the following slides:
   - Celery epidermis (outer layer of the celery stem) with and without methylene blue stain
   - Squashed ripe and unripe banana with and without iodine
   - A very thin slice of potato with iodine.

Results

Create detailed scientific drawings of your observations under the microscope. Include a clear title, the magnification used and label all visible structures/organelles.

Discussion

1. Compare the cells of the stained onion epidermis and the celery epidermis (or potato). Identify their similarities and differences. Suggest reasons for the differences.
2. Identify their similarities and differences if a ripe and an unripe banana were used. Suggest reasons for the differences.

Methylene blue is used to stain the nucleus so that it is easier to see. Iodine changes from yellow-brown to a dark blue when it combines with starch.

3. Explain why stains are used. Include reasons for using methylene blue and iodine that relate to your observations in this investigation.
4. Investigate the functions of the structures observed in your stained specimens. Explain how the features of these structures support their function.
5. Analyse the strengths, limitations and potential improvements of this investigation.

Conclusion

Summarise the findings for this investigation.

DISCUSSION

1. Why is it important to make the specimen thin enough for light to pass through?
2. How do stains like methylene blue or iodine help scientists see cell structures more clearly?
3. Why is it important to use a cover slip when preparing a specimen?

2.5 Activities

2.5 Quick quiz	2.5 Exercise

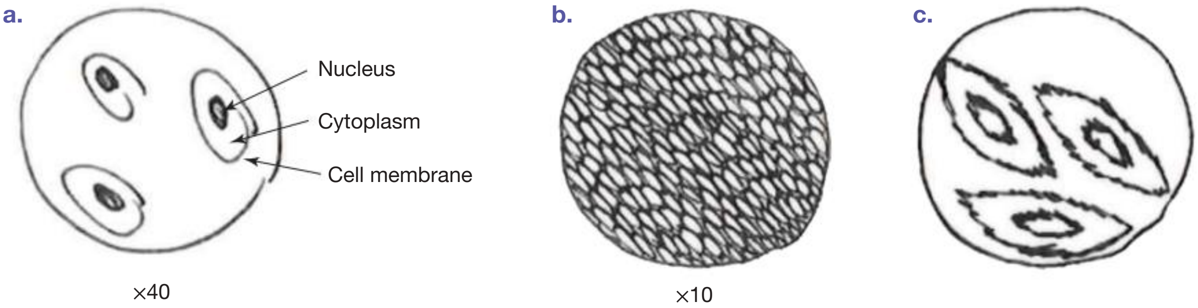
LEVEL 1	LEVEL 2	LEVEL 3
1, 3	2, 4	5, 6

Remember and understand

1. **a.** Carefully observe the image of plant cells given and **construct** a sketch of one of the cells.
   b. Use references to **suggest** labels for the structures shown in your sketch.

Apply and analyse

2. SI Carefully observe the student sketches shown. For each diagram, **list** what is wrong with it and suggest how it could be improved.



3. Microscope slides are provided along with a specimen of onion skin and a dye to highlight its cell features. **Describe** the steps you would take to prepare the specimen for viewing under a microscope, explaining how you use the dye in the process.

Evaluate and create

4. SI Design a poster that shows others how to prepare a variety of specimens to be viewed under a microscope.
5. SI Methylene blue has the following warning symbols on the Safety Data Sheet that need to be considered when it is used.

   a. **Explain** what these symbols mean.
   b. **Explain** what precautions should be taken when using methylene blue.
6. Develop a plan for testing how different dyes affect the visibility of various cell structures in specimens. Include the steps for preparation, observation and recording, as well as a method for comparing the effectiveness of the dyes used.

Answers and sample responses are available in your digital formats.

LESSON 2.6 Focus on animal cells

LEARNING INTENTION

In this lesson you will describe how cell shape and size (form) enables the functions of animal cells.

2.6.1 In all shapes and sizes

Cells within an organism may differ in their shape and size. This difference may be due to the particular jobs or functions that the cells carry out within the organism. The human body is made up of more than 20 different types of cells, with each type suited to a particular function.

Nerve cells develop long, thin fibres that quickly carry messages from one cell to another. Cells lining the trachea have hair-like cilia that move fluid and dust particles out of the lungs. Muscle cells contain fibres that contract and relax, and the human sperm cell has a tail, or flagellum, that helps it swim to the egg cell.

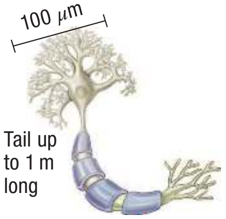
Cells can also differ in the organelles that they contain within them. Muscle cells, for example, contain more mitochondria than other types of cells due to their high energy requirements. Red blood cells also differ from many other types of cells because, as they mature, they lose their nucleus. This makes more room available for them to carry more oxygen throughout your body.

EXTENSION: Facts about human cells

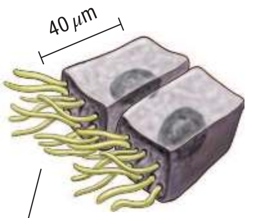
Did you know these facts about human cells?

- Hair and nails are made of dead cells, and because they are not fed by blood or nerves you can cut them without it hurting.
- A human baby grows from one cell to 2000 million cells in just nine months.
- Red blood cells live for one to four months and each cell travels around your body up to 172 000 times.
- Some of the nerve cells in the human body can be 1 m long. But that's small compared with the nerve cells in a giraffe's neck. They are 2 to 3 m long!

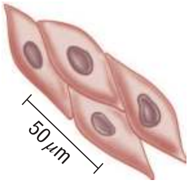
FIGURE 2.27 The human body is made up of more than 20 different types of cells, with each type suited to a particular function.



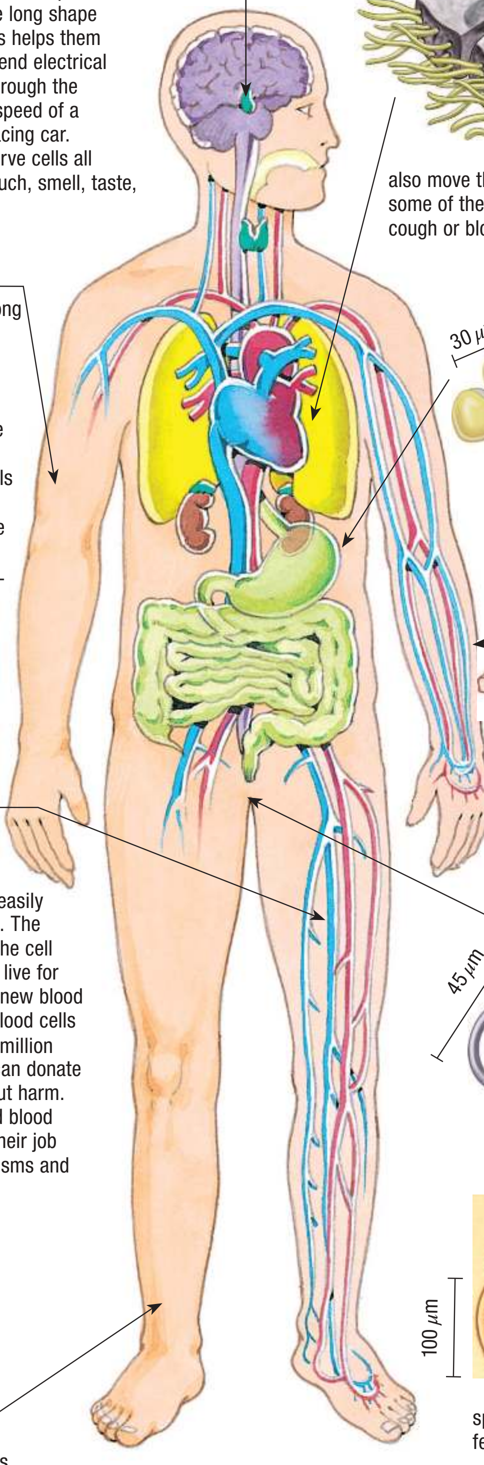
Nerve cells
Nerve cells are very long and have a star shape at one end. The long shape of nerve cells helps them detect and send electrical messages through the body at the speed of a Formula 1 racing car. There are nerve cells all over your body. They allow you to detect touch, smell, taste, sound, light and pain.

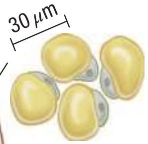


Lung epithelial cells
The cells that line your nose, windpipe and lungs are a type of lining cell. They have hair-like tips called cilia. These cells help protect you by stopping dust and fluid from getting down your windpipe. The cilia can also move these substances away from your lungs. You remove some of these unwanted substances whenever you sneeze, cough or blow your nose.

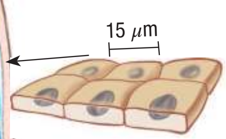


Muscle cells
Muscle cells are long and elastic. Long thin cells can slide further over each other to allow you to move. There are different types of muscle cells. The walls of your blood vessels and parts of your digestive system have 'smooth muscle' cells. The muscles that are joined to your bones are called 'skeletal muscles'. Skeletal muscles work in pairs — one muscle contracts (shortens) and pulls the bone in one direction while the other muscle relaxes.

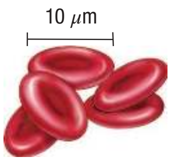




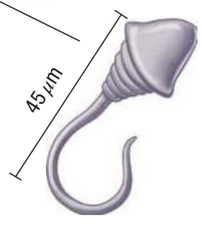
Adipose tissue cells
Some cells store fat. Fat stores a lot of energy for cells to use later. Round shapes are good for holding a lot of material in a small space. Fat cells are mostly found underneath your skin, especially in the chest, waist and buttocks.



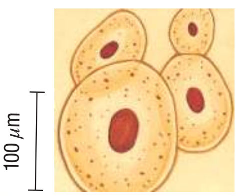
Skin cells
Special cells line the outside surfaces of your body. These are the cells that form your skin. These cells have a flattened shape so they can better cover and protect your body.



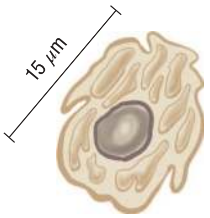
Red blood cells
Red blood cells carry oxygen around the body. Their small size allows them to move easily through blood vessels. The nucleus in a red blood cell dies soon after the cell is made. Without a nucleus, red blood cells live for only a few weeks. The body keeps making new blood cells to replace those that have died. Red blood cells are made in bone marrow at the rate of 17 million cells per minute! This is why most people can donate some of their blood to the Red Cross without harm. White blood cells, which are larger than red blood cells, are also made in the bone marrow. Their job is to rid the body of disease-causing organisms and foreign material.



Sperm cells
Sperm cells have long tails that help them swim towards egg cells. Only males have sperm cells.



Egg cells
Egg cells are some of the largest cells in a human body. Their large round shape helps them store plenty of food. Only females have egg cells. When a sperm cell moves into an egg cell, the egg cell is fertilised.



Bone cells
Minerals such as calcium surround your bone cells. The minerals help make bone cells hard and strong. Bone cells need to be hard so that they can keep you upright.

INVESTIGATION 2.5

Animal cells — what's the difference?

Aim

To observe and analyse the features of various human (animal) cells

Materials

- light microscope
- prepared animal slides: blood cells, muscle cells, cheek cells, nerve cells

Method

Use a microscope to observe the prepared slides.

Results

Record detailed diagrams of your observations. Next to your diagrams, include details of the (a) source of the specimen, (b) type of specimen, (c) magnification used as well as (d) a detailed description of the specimen.

Discussion

1. Compare the sizes of the animal cells you observed and explain any differences or similarities.
2. Determine whether all the observed cells contained a nucleus and explain your observations.
3. Identify and describe the common features shared by all the observed animal cells.
4. Identify and explain the differences in the features of the observed cells.
5. Suggest reasons for the differences between the cells.
6. Compare your cells with those in figure 2.27.
   a. Do your sketched diagrams match the structures shown in the figure? Explain.
   b. Read through the text related to the functions of the different types of cells. Do these match those you suggested in question 5? Explain.

Conclusion

Summarise the findings for this investigation.

Extension

What are the similarities and differences between human blood cells compared to other animals such as frogs?

SCIENCE AS A HUMAN ENDEAVOUR: How scientists work together to study cells

Understanding how cells function requires teamwork and collaboration among scientists from various fields. Biologists focus on studying the structure, composition and specific roles of cells within the body. Engineers and physicists contribute by developing tools such as electron microscopes and computer imaging programs, which enable scientists to closely examine cells and observe their processes in real time. Medical researchers build upon these findings to develop treatments for diseases, including creating medicines and artificial tissues or organs.

An example of this collaboration is in the study of diseases. When researching diseases such as cancer and their effects on cells, scientists needed microscopes capable of revealing intricate details within the cells. Engineers responded by designing advanced microscopes that magnify structures such as the nucleus and mitochondria. These innovations have greatly improved doctors' understanding of cancer progression and the effectiveness of targeted treatments.

Integrating knowledge from diverse cultures and parts of the world also plays a key role in advancing scientific understanding. Indigenous knowledge, which often emphasises the interconnectedness of living systems, inspires scientists to consider how cells collaborate within larger systems in the body. Global collaboration among scientists fosters faster problem-solving and drives the creation of impactful solutions, such as affordable medicines and sustainable technologies.

1. How do scientists from different areas, such as biology, engineering and medicine work together to study cells? How does their teamwork lead to new discoveries or technologies?
2. What challenges might scientists face when working as a team on large projects, and how can they overcome these challenges to improve our understanding of cells?

Multidisciplinary endeavours to advance scientific knowledge make use of people's different perspectives and worldviews (VC2S8H02)

2.6 Activities

learnon

2.6 Quick quiz on | **2.6 Exercise**

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3	4, 5, 7	6, 8, 9

Remember and understand

1. Match the types of cells with their descriptions.

Type of cell	Description
a. Muscle cell	**A.** Has a long tail that helps it to swim towards the egg cell
b. Skin cell	**B.** Long, thin elastic cell that contracts and relaxes
c. Red blood cell	**C.** Flat cell that lines the outside surface of your body
d. Nerve cell	**D.** Very tiny cell that lacks a nucleus when mature, and carries oxygen
e. Sperm cell	**E.** Very long cell, star-shaped at one end; detects and sends messages

2. **Identify** which features most animal cells have in common.
3. **Describe** some ways in which cells may differ.
4. **Suggest** why the cells in a multicellular organism are not all the same. Give examples in your answer.

Apply and analyse

5. **Compare** and **explain** the differences between:
   a. skin cells and sperm cells
   b. red blood cells and nerve cells
   c. adipose tissue cells and muscle cells.
6. a. SI **Summarise** the information from figure 2.27 into a table with the headings: 'Type of cell', 'Function', 'Shape' and 'Size'.
   b. Using this information, **deduce** the average size of an animal cell.
   c. Use a column graph to plot the sizes of the different types of animal cells.
   d. **Identify** which animal cells are 'above average' in size and which are 'below average'. **Suggest** reasons for the differences.
7. Heart cells have large numbers of mitochondria. **Explain**, with reference to the function of the heart cell, why this is the case.

Evaluate and create

8. **Explain** how the shape and size of different animal cells enable them to perform their specific functions. Provide examples of at least three different types of animal cells, describe their shapes and sizes, and explain how these characteristics help them carry out their roles effectively.
9. Design a poster or infographic that illustrates how the shape and size of different animal cells supports their functions. Include labelled diagrams and explanations.

Answers and sample responses are available in your digital formats.

LESSON 2.7 Focus on plant cells

LEARNING INTENTION

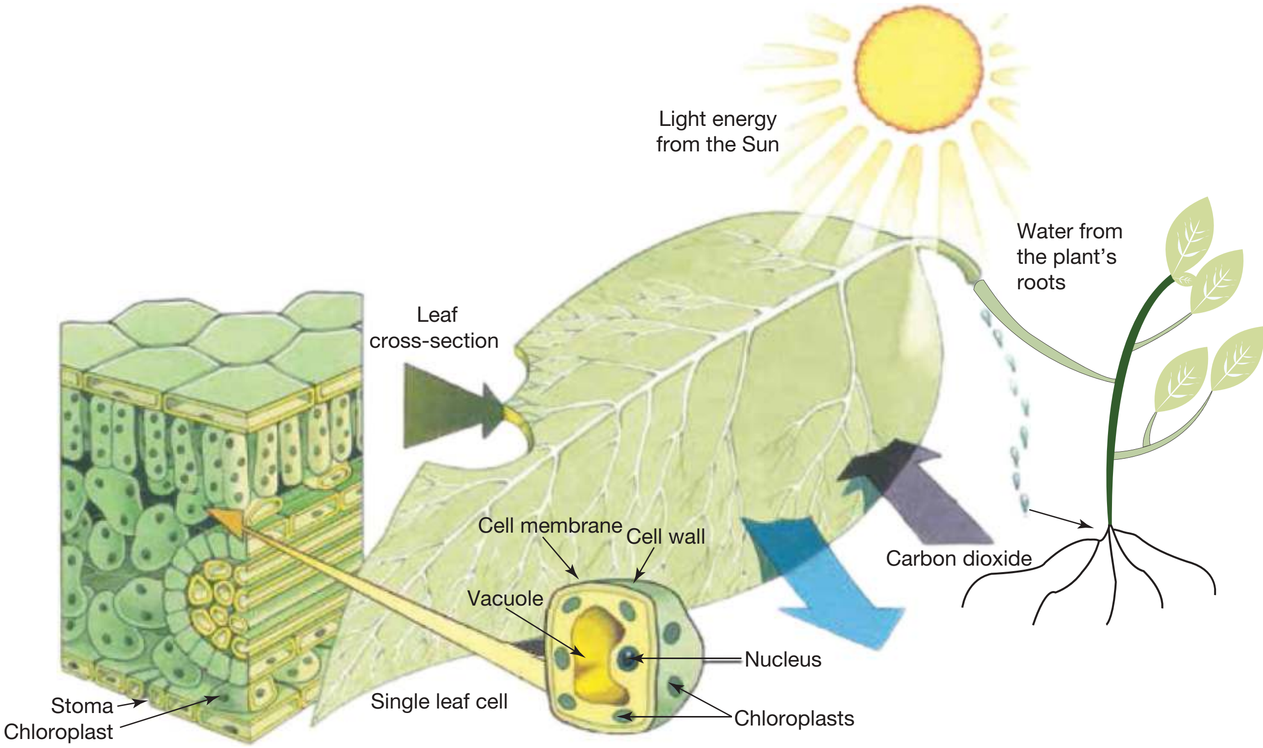
In this lesson you will identify and describe cells that are specialised in plants.

2.7.1 Have or have not

Like animal cells, plant cells have cytoplasm, a membrane and a nucleus. Unlike animal cells, plant cells have a cellulose cell wall and a large central **vacuole** filled with cell sap. Often, plant cells also contain chloroplasts in their leaves, which enable them to make their own food in a process called photosynthesis. In this process, carbon dioxide (from the air) and water (from the roots) move into the chloroplast, leading to the production of glucose (used by the plant) and the release of oxygen.

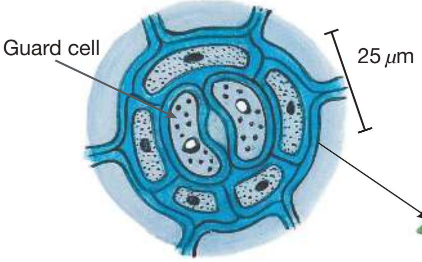
$$\text{carbon dioxide} + \text{water} \rightarrow \text{glucose} + \text{oxygen}$$

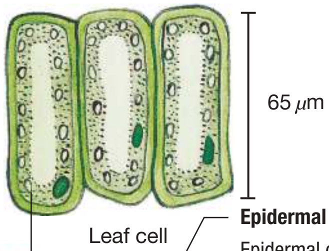
FIGURE 2.28 The process of photosynthesis in the leaves of plants



On the surfaces of leaves, there are pairs of specialised cells called **guard cells**, which surround tiny pores called **stomata**. The guard cells can change shape, opening or closing the stomata. Special cells on the roots extend into microscopic hairs that penetrate between soil particles. The hairs provide a large surface area through which water may be absorbed from the soil.

FIGURE 2.29 Some of the types of cells found in plants



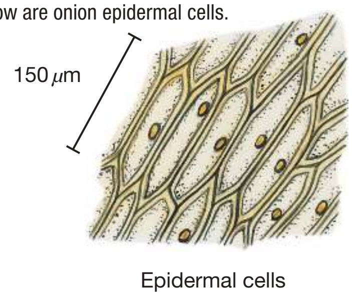


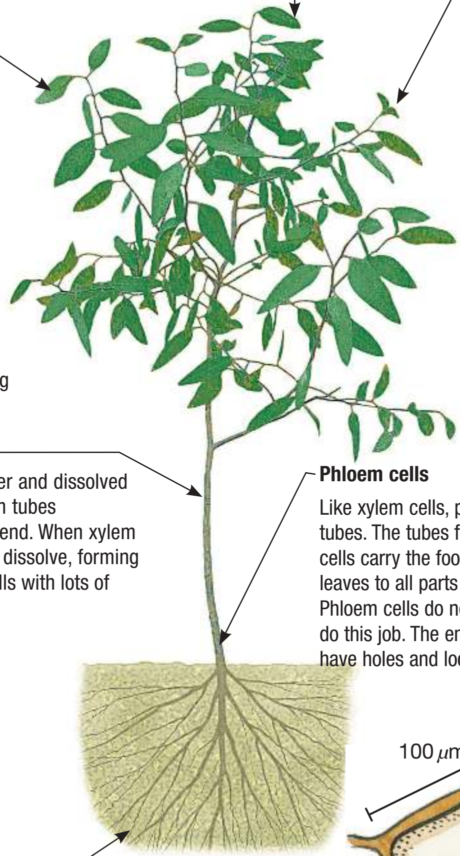
Leaf cells (palisade cells)

The main function of leaf palisade cells is to photosynthesise, so they are packed with chloroplasts and are usually green.

Epidermal cells

Epidermal cells are found on the outside of the plant. They form an outer skin for the plant and protect the cells underneath. This explains why they need a flat shape and why they interlock like tiles. Epidermal cells do not usually photosynthesise so they lack chloroplasts. Light needs to pass through them, and they are usually transparent. The cells in the diagram below are onion epidermal cells.





Guard cells

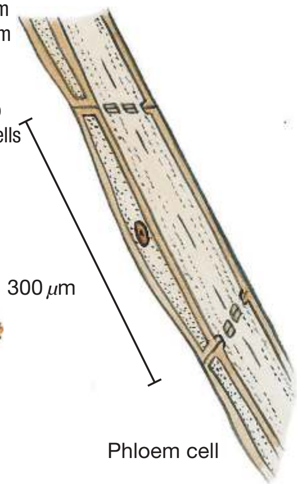
Guard cells are kidney-shaped cells found on the surface of leaves. They can change shape to either open or close the small hole between them. The small holes found mostly on the bottom side of the leaf, called stomata (or stomates), allow substances such as carbon dioxide to enter the leaf. They also let water out of the leaf. Most plants open their stomata at night; they close their stomata during the day (when it is hotter) to conserve water.

Xylem cells

Xylem cells form xylem tubes, which carry water and dissolved minerals up the plant and into the leaves. Xylem tubes are made up of dead xylem cells joined end to end. When xylem cells die, the cell walls at each end of the cells dissolve, forming a long, straw-like tube. They have thick cell walls with lots of cellulose to make the xylem tubes strong.

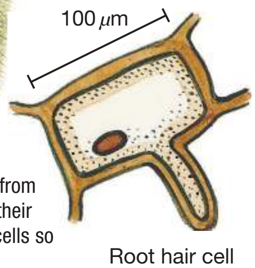
Phloem cells

Like xylem cells, phloem cells form tubes. The tubes formed by phloem cells carry the food made in the leaves to all parts of the plant. Phloem cells do not need to die to do this job. The ends of phloem cells have holes and look like sieves.



Root hair cells

Root hair cells absorb water and dissolved minerals from the soil. They have small hairs, called root hairs, on their surface. This increases the surface area of the root cells so that they can soak up water more quickly.



KEY IDEA

The word 'xylem' comes from the Greek word *xulan*, meaning 'wood'. The word 'phloem' comes from the Greek word *phloos*, meaning 'bark'.

SCIENCE INQUIRY: Analysing patterns and identifying anomalies in cell data

Once data is collected from cell investigations, it is organised into graphs, tables or models to identify patterns and trends. For instance, scientists might compare the number of chloroplasts in leaf cells from plants grown in sunlight versus shade. A clear pattern could emerge, showing that sunlight exposure increases chloroplast numbers, which are essential for photosynthesis.

However, not all data fits neatly into expected patterns. These inconsistencies, or anomalies, are valuable because they often lead to new questions. For example, if a plant grown in full sunlight has fewer chloroplasts than expected, scientists might investigate whether the plant has a disease or a genetic mutation affecting chloroplast production.

The process of analysing data helps scientists refine their understanding of cells and their functions. It also highlights the importance of accuracy in data collection and the need to consider variables that might affect results, such as environmental conditions or experimental errors. Recognising patterns and addressing anomalies is a critical skill for advancing scientific knowledge.

1. What patterns can we observe in the size and structure of different cell types, such as nerve cells or red blood cells?
2. How can scientists explain anomalies in data about organelle counts, like fewer mitochondria in muscle cells?
3. What new questions might arise if experimental data about cells doesn't match predictions?

Scientific methods, conclusions and claims can be analysed to identify assumptions, possible sources of error, conflicting evidence and unanswered questions (VC2S8I06)

INVESTIGATION 2.6

Plant cells in view

Aim

To observe and analyse the structural features of various types of plant cells

Materials

- light microscope
- prepared plant slides: leaf epidermal cells, root hair cells, stomata/guard cells

Method

Use a microscope to observe the prepared slides.

Results

Record detailed diagrams of your observations. Next to your diagrams, include details of the (a) source of the specimen, (b) type of specimen, (c) magnification used as well as (d) a detailed description of the specimen.

Discussion

1. Compare the sizes of the observed plant cells and explain any differences or similarities.
2. Determine whether all the observed plant cells contain a nucleus and explain your findings.
3. Identify and describe the common features shared by all the observed plant cells.
4. Identify and explain the differences in the features of the observed plant cells.
5. Suggest and explain reasons for the differences observed between the plant cells.
6. Compare your cells with those in figure 2.29.
   a. Do your sketched diagrams match the structures shown in the figure? Explain.
   b. Read through the text related to the functions of the different types of cells. Do these match your answer to question 5? Explain.

Conclusion

Summarise the findings for this investigation.

2.7 Activities

learnon

2.7 Quick quiz on	2.7 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2	3, 5, 6	4, 7

Remember and understand

1. Match the types of cells with their descriptions.

Type of cell	Description
a. Guard cells	A. Sieve-like cells that form tubes that carry food made in the leaves to other parts of the plant
b. Phloem cells	B. Cells with small hairs that increase their surface area so that they can absorb more water
c. Xylem cells	C. Thick-walled cells that carry water up the plant
d. Root hair cells	D. Kidney-shaped cells that can change shape to either open or close the small hole between them, which allows gas exchange between the plant and its environment

2. **Describe** some ways in which plant cells may differ.

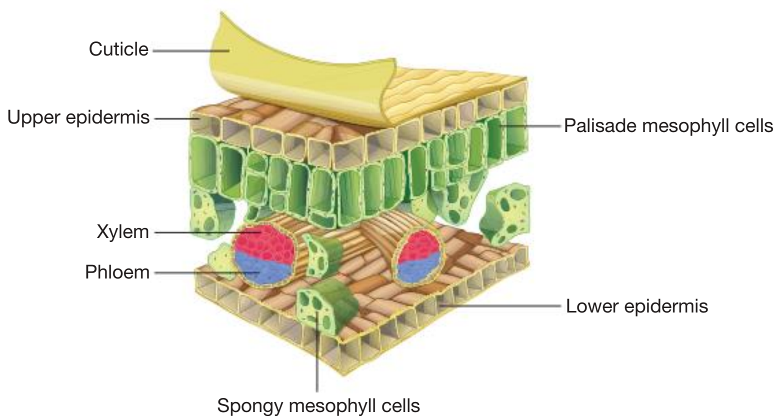
Apply and analyse

3. **Compare** and **explain** the differences between:
   a. palisade cells and guard cells
   b. xylem cells and phloem cells
   c. epidermal cells and root hair cells.
4. a. SI **Summarise** the information in figure 2.29 into a table with the headings: 'Type of cell', 'Function', 'Shape' and 'Size'.
   b. Using this information, **deduce** the average size of a plant cell.
   c. **Construct** a bar graph to plot the sizes of the different types of plant cells.
   d. **Identify** which plant cells are 'above average' in size and which are 'below average'. Suggest reasons for the differences.
   e. Comment on the differences in other features between plant cells.

Evaluate and create

5. **Construct** a model of a pair of guard cells, using balloons.
6. **Identify** and describe three types of specialised cells in plants. **Explain** how the structure of each cell type is adapted to its specific function within the plant. For example, consider cells like guard cells, xylem cells and phloem cells, and discuss how their unique features enable them to perform their roles effectively.

7. SI Consider the following diagram of a leaf.
In most leaves, sunlight hits the upper side of the leaf. The light penetrates (passes through) the upper epidermis before hitting the palisade mesophyll cells.



a. The mesophyll cells all have chloroplasts. **Describe** the function of chloroplasts.
b. **Suggest** a reason the palisade mesophyll cells have more chloroplasts than the spongy mesophyll cells.
c. During photosynthesis, water is taken up by the roots and combined with carbon dioxide in the air. Glucose is made and stored for future use and oxygen is released. **Describe** the role of the large air spaces between the spongy mesophyll cells.
d. **Explain** why there are more stomata on the under surface of the leaf.

Answers and sample responses are available in your digital formats.

LESSON 2.8 Plant cells — holding, carrying and guarding

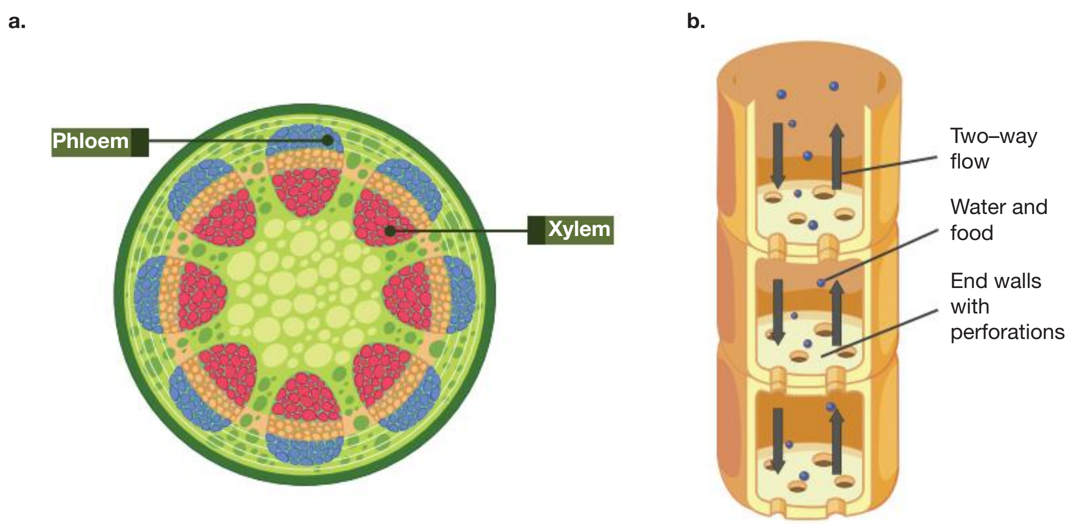
LEARNING INTENTION

In this lesson you will be able to describe the specialised transport systems in plants.

2.8.1 Sweet transport — phloem

As in animal cells, plant cells can work together for a variety of functions to meet their survival needs. Plants have their own transport systems, which consist of many thin tubes made up of different types of cells. Other types of plant cells are involved in water regulation and exchange of important gases, such as oxygen and carbon dioxide, with their environment.

FIGURE 2.30 a. Phloem helps transport and distribute nutrients around the plant. **b.** The structure of phloem allows these nutrients to be transported upwards as well as downwards.



Using the process of photosynthesis, plants make sugar in their leaves. The **phloem** is a system of thin-walled tubes (that are found in the outer part of the stem) that carries this sugar (in the form of glucose or sucrose) from the leaves to other parts of the plant. Phloem consists of living cells called sieve tubes and companion cells. The transport of the sugar solution up and down the plant is called **translocation**.

2.8.2 Water pipes — xylem

Flowering plants also have tubes with strong, thick walls that carry water and minerals up from the roots through the stem to the leaves. These are called **xylem vessels** and are located towards the centre of the stem (figure 2.30a). These tubes are formed from the empty remains of dead cells, the walls of which are strengthened with a woody substance called **lignin**. The xylem is therefore a 'dead' one-way street (figure 2.31), rather than a 'living' two-way highway like phloem.

Water moves up from the roots of the plant, through its stem and to its leaves, where some water may pass out of the plant as water vapour through pores called stomata. This movement of water is called the **transpiration stream** (figure 2.32).

FIGURE 2.31 The flow of water and minerals is only one way in xylem, away from the roots.

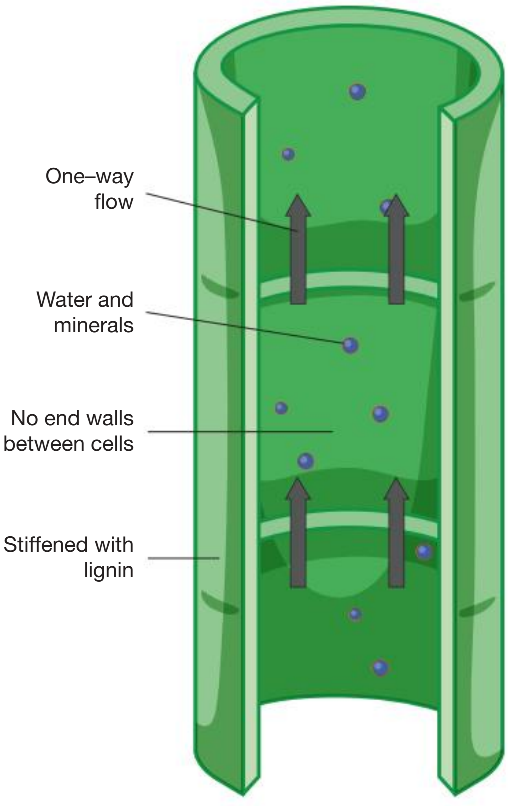
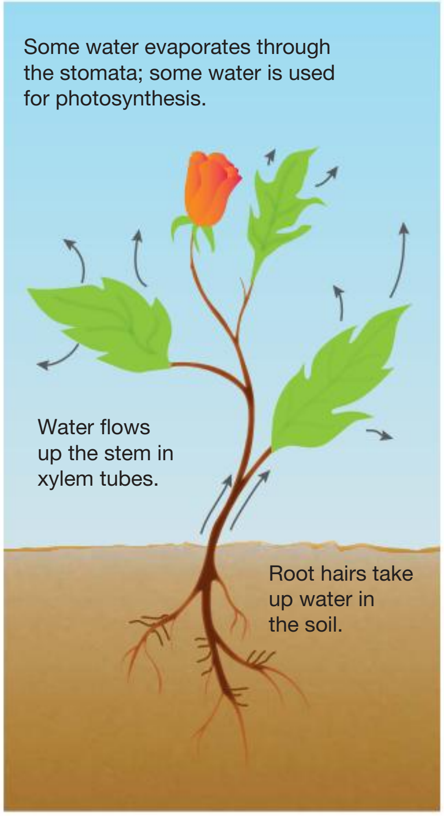


FIGURE 2.32 The movement of water from roots to leaves is known as the transpiration stream.



INVESTIGATION 2.7

Stem transport systems

Aim

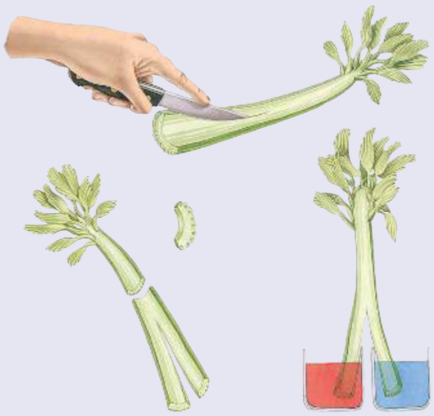
To identify xylem cells in celery

Materials

- celery stick (stem and leaves)
- knife
- two 250-mL beakers
- water
- blue food colouring
- red food colouring
- hand lens

Method

1. Slice the celery along the middle to about halfway up the stem.
2. Fill two beakers with 250 mL of water. Colour one blue and the other red with the food colouring.
3. Place the celery so that each 'side' of the celery is in a separate beaker.
4. Leave for 24 hours and then observe the celery.
5. Cut the celery stick across the stem.
6. Use the hand lens to look at the inside of the stem.



Results

1. Look at where the water has travelled in the celery. Draw a diagram to show your observations.
2. Draw a diagram to show what you can see when you cut across the stem.
3. Where are the different colours found in the stem?
4. Where are the different colours found in the leaves?
5. Draw a diagram of the whole celery stick and trace the path of the water through each side to the leaves.

Discussion

1. Explain your observations of where the water was found in the stems and leaves. Make sure you comment on the relationship between the shape of the structures and your findings.
2. Identify strengths and limitations of this investigation and suggest possible improvements.

Conclusion

Summarise the findings for this investigation.

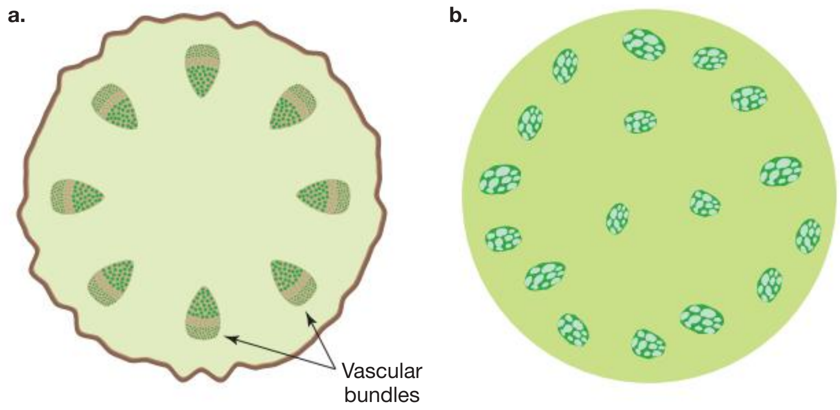
Extension

How could you turn a white carnation blue? Try it.

Xylem for support

The phloem and the xylem vessels are located together in groups called **vascular bundles**. The strong, thick walls of the xylem vessels are also important in helping to hold up and support the plant. The trunks of trees are made mostly of xylem. Did you know that the stringiness of celery is due to its xylem tissues?

FIGURE 2.33 The vascular bundles can appear different depending on the plant. They can either **a.** be in a ring-like pattern around the stem or **b.** have a random arrangement throughout the stem.



DISCUSSION

1. Why is it important for plants to have both xylem and phloem?
2. How are xylem and phloem similar, and how are they different?
3. What might happen to a plant if its xylem or phloem were damaged?

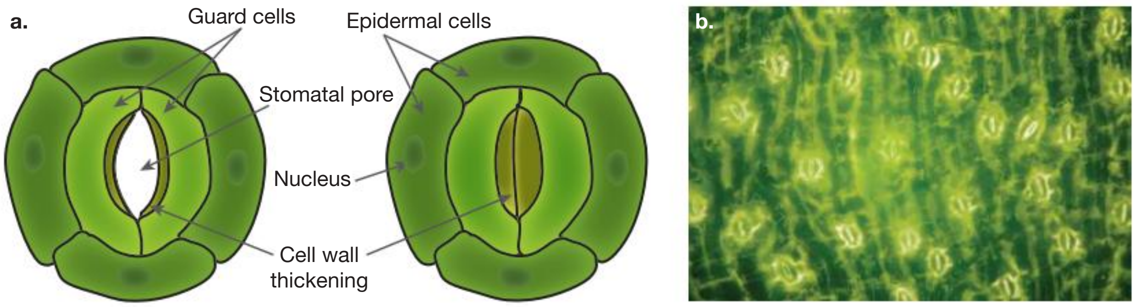
2.8.3 Leaf doorways — stomata

Water transport occurs within the xylem vessels. Some of the water that is transported through the xylem to the leaves is used in photosynthesis. Some water is also lost as water vapour through tiny holes or pores in the leaves. These tiny pores, called stomata (or stomates), are most frequently found on the underside of the leaves. Evaporation of water from the stomata in the leaves helps pull water up the plant. Loss of water vapour through the stomata is called **transpiration**.

Guard cells in control

Oxygen and carbon dioxide gases also move in and out of the plant through the stomata. Guard cells, which surround each stoma, enable the hole to open and close, depending on the plant's needs. When the plant has plenty of water, the guard cells fill up with water and stretch lengthwise. This opens the pore. If water is in short supply, however, the guard cells lose water and they collapse towards each other. The pore is then closed. This is one way in which the plant can control its water loss.

FIGURE 2.34 **a.** Stomata can open (left) and close (right) to conserve water. **b.** What features can you identify in this image of a leaf under a microscope?



INVESTIGATION 2.8

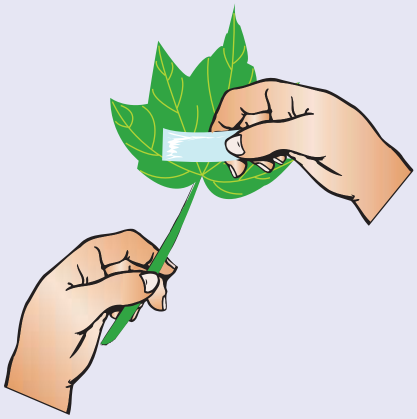
Observing leaf epidermal cells

Aim

To examine leaf epidermal cells under a microscope and identify the presence and structure of stomata

Materials

- leaf
- clear sticky tape
- microscope slide
- microscope



Method

1. Put some sticky tape over a section of the underside of the leaf.
2. Press the sticky tape firmly onto the leaf.
3. Tear the tape off. Some of the lining cells should come off with the sticky tape.
4. Press the tape, sticky side down, onto a microscope slide.
5. View the sticky tape under the microscope.
6. Try to find a pair of guard cells and one of the stomata.

Results

1. Observe and record whether the stoma (the opening) is open or closed.
2. Create a detailed scientific diagram of a group of cells, including the guard cells and stomata. Ensure the diagram is accurately labelled, and includes a clear title, date and magnification used, and captures as much detail as possible.

Discussion

1. Summarise your findings, explaining the relationship between the shape of the observed structures and their functions.
2. Describe the processes that cause guard cells to change, resulting in the opening and closing of stomata.
3. Evaluate the strengths and limitations of this investigation and propose potential improvements.

Conclusion

Summarise the findings for this investigation.

EXTENSION: Water loss

Although water makes up about 90–95 per cent of the living tissues of plants, water is often being lost to their surroundings. As much as 98 per cent of the water absorbed by a plant can be lost through transpiration.
A variety of factors affect the amount of water that plants lose. Weather is a major factor, as high temperatures, wind and low humidity can increase the evaporation of water from the stomata. Researchers have recorded water losses in large trees of more than 400 L in a single day.

INVESTIGATION 2.9

Looking at chloroplasts under a microscope

Aim

To observe and examine chloroplasts in plant cells using a light microscope

Materials

- tweezers
- water
- moss, spirogyra or elodea
- dilute iodine solution
- light microscope, slides, coverslips

Method

1. Using tweezers, carefully remove a leaf from a moss or elodea plant or take a small piece of spirogyra.
2. Place the plant material in a drop of water on a microscope slide and cover it with a coverslip.
3. Use a light microscope to observe the leaf. Complete a drawing of a cell. Include (a) title, (b) magnification, (c) scale bar and (d) appropriate labels.
4. Put a drop of dilute iodine solution under the coverslip. (Iodine stains starch a blue-black colour.)
5. Using the microscope, examine the leaf again. Complete a drawing of a cell. Include (a) title, (b) magnification, (c) scale bar and (d) appropriate labels.

Results

1. Create a detailed scientific diagram of your observations under the microscope before staining.
2. Refer to your previous observations and clearly label any chloroplasts visible in your scientific diagram.

Discussion

1. Observe and describe the colour of the chloroplasts before staining.
2. Identify the organelles responsible for the colour of chloroplasts and explain their role.
3. Determine whether the Iodine stained any part of the leaf a dark colour and explain what this observation suggests.
4. Identify the strengths and weaknesses of this investigation and propose changes to improve its effectiveness and reliability.

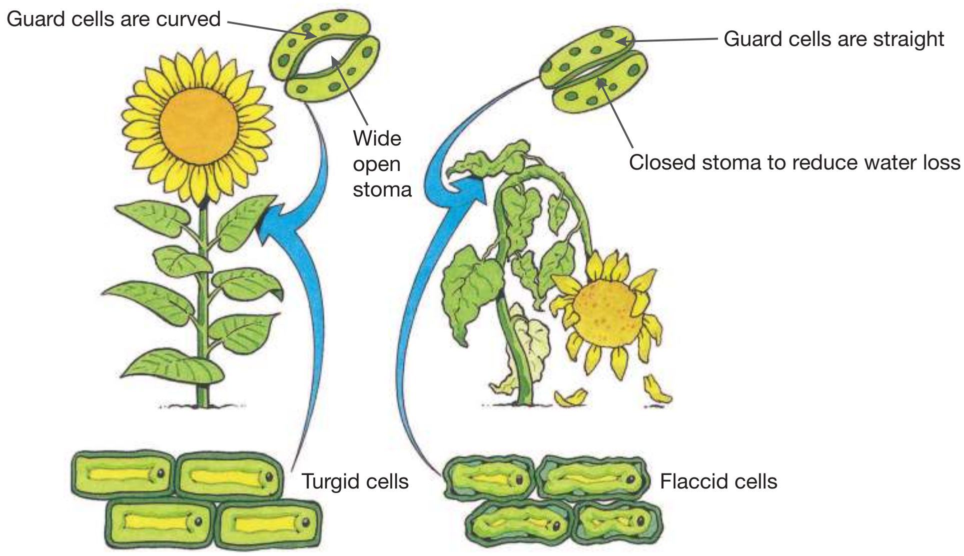
Conclusion

Summarise the findings for this investigation about chloroplasts.

Flaccid or firm?

If too much water is lost or not enough water is available, the plant may **wilt**. When this occurs, water has moved out of the cell vacuoles and the cells have become soft or **flaccid**. The firmness in the petals and leaves is due to their cells being firm or **turgid**.

FIGURE 2.35 If the cells of a plant do not contain enough water, they become flaccid and the plant wilts.



INVESTIGATION 2.10

Moving in or out?

Water moves from areas of high water concentration to areas of low water concentration. In this way, water can move from the xylem cells into photosynthetic cells so that photosynthesis can occur. In this investigation you will see how water moves across a membrane.

Aim

To construct a cell membrane model to demonstrate the movement of water into and out of a cell

Hypothesis

What do you expect will happen to Bag A?

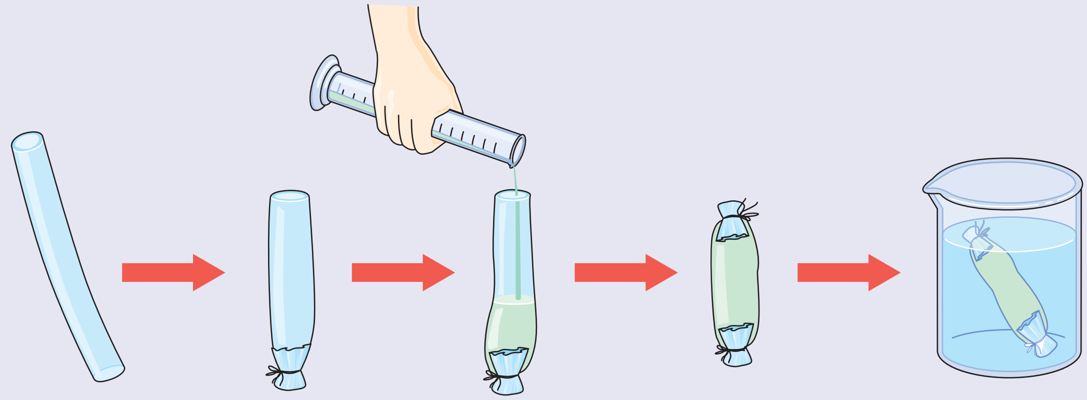
What do you expect will happen to Bag B?

Materials

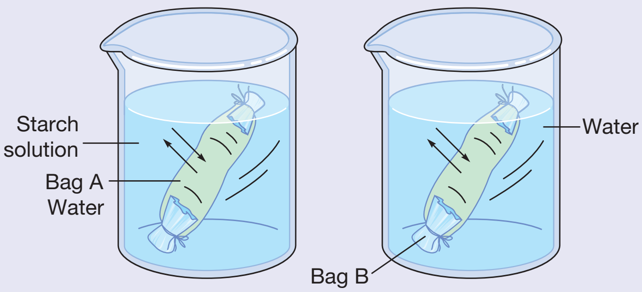
- two 20-cm lengths of dialysis tubing
- scales
- starch solution
- iodine solution
- two beakers
- string or food packaging pegs

Method

1. Soak the dialysis tubing in water so it becomes soft.
2. Tie a knot at one end of each piece of dialysis tubing. This will form two small bags.
3. Pour water into Bag A until it is one–third full. Pour the same amount of starch solution into Bag B and add ten drops of iodine solution.
4. Tie a knot at the top of each bag to seal them or use the string/food packaging pegs.
5. Weigh each bag and record the weights in the table in the results section of this investigation.



6. Put Bag A in a beaker of starch solution. Add enough iodine to the starch solution to produce a dark blue colour.
7. Put Bag B in a beaker of water.
8. Leave the two bags undisturbed for at least two hours (or overnight).
9. Weigh the bags again. Record in the table in the results section.
10. Draw Bags A and B in the beakers they were left in. On your diagram, label where blue and yellow colour can be seen.



Results

Copy and complete a table such as the one shown. Give your table an appropriate title.

Weight	Bag A (bag of water in starch solution)	Bag B (bag of starch in water solution)
Before		
After		

Discussion

1. Identify and explain which part of the model represented the cell membrane in this experiment.
2. Describe and explain what happens to Iodine when it is added to a starch solution.
3. Dialysis tubing allows some substances, but not others, to pass through. Which of the following substances could pass through the dialysis tubing and which could not? What evidence supports this?
   a. Starch
   b. Water
   c. Iodine
4. Determine whether the masses of the two bags changed and explain the factors that caused the change or lack of change.
5. When water moves in or out of cells by osmosis, it moves in the direction that balances the concentrations of substances inside and outside the cell. Explain why the masses of the bags changed.
6. Analyse the strengths and limitations of this investigation and propose possible improvements.

Conclusion

Summarise the findings for this investigation.

Dusty doors

Air pollution can result in particles of dust settling on the leaves of plants. This may limit the amount of light reaching the leaf and therefore reduce photosynthesis. If these dust particles block up the stomata, they can also affect transpiration and gas exchange.

EXTENSION: Genetically engineered plants

Scientists have used genetic engineering to produce plants that glow particular colours when they have mineral deficiencies. This provides farmers with information about which soils need extra minerals added.

2.8 Activities

learnon

2.8 Quick quiz on	2.8 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 4, 6	5, 8, 10, 13	7, 9, 11, 12

Remember and understand

1. **State** the name used for the tubes that carry sugar solution around a plant.
2. **Describe** the importance of vascular bundles to plants.
3. **State** two things that may happen to water in a plant.
4. On which part of the plant are stomata usually found?
5. **Identify** the mechanism that helps pull water upwards in a plant.

Apply and analyse

6. **Explain** the difference between:
   a. phloem and xylem vessels
   b. sugar and water transport in plants.
7. **Describe** how the guard cells assist the plant in controlling water loss.
8. **Describe** the difference between flaccid cells and turgid cells.
9. Copy and complete the table given.

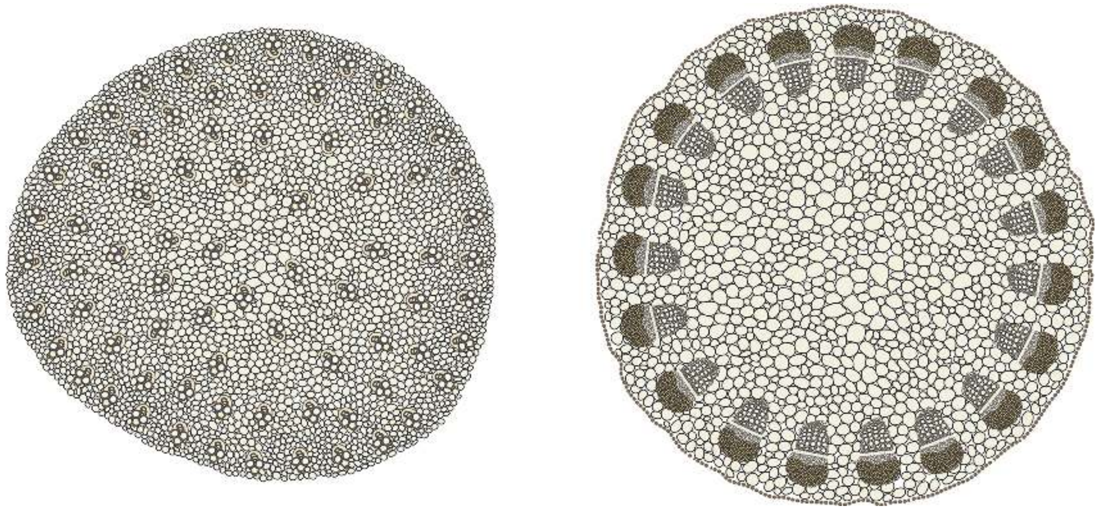
Tissue	What it carries	Direction of movement	Name of cells that form tubes	Are cells that form tubes living?
Xylem				
Phloem				

Evaluate and create

10. Carefully **examine** the reaction for photosynthesis as shown.

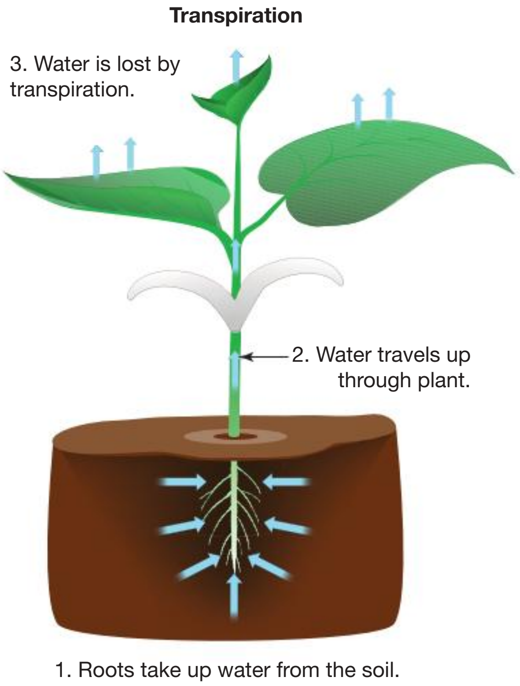
$$\text{carbon dioxide + water} \xrightarrow[\text{chlorophyll}]{\text{light energy}} \text{glucose + oxygen (+ water)}$$

   a. **State** why water and carbon dioxide are so important to plants.
   b. **State** why guard cells are important to plants.
   c. **Predict** consequences for a plant if the guard cells close the stomata for long periods of time.
11. SI Grasses and trees have a very different arrangement of their vascular bundles.



The image on the left is the organisation in a grass stem (random) and the image on the right is that of a stem that eventually becomes a tree (organised in a ring).
MC Choose the feature of trees that you think this specialised arrangement leads to.
A. Roots
B. Leaves
C. Wood
D. Flowers

12. SI This diagram demonstrates transpiration, the loss of water from the leaves of a plant.



a. Hypothesise what you would expect the rate of transpiration to do in the following scenarios:
   i. Wind speed increases
   ii. Temperature increases
   iii. Humidity increases.
b. When a plant experiences water stress because there is not enough water, the guard cells lose water and become flaccid, thereby closing the stomata.
   i. Draw a diagram of this process.
   ii. Hypothesise what you would expect to happen to photosynthetic rate.
   iii. What dependent variable could you measure to test your hypothesis from part **b ii**?
   iv. Design an experiment to measure the amount of water lost through the leaves of a plant. Remember to include the following:
      - What will change?
      - What will stay the same?
      - What will be measured?
      - How will the test be repeatable?

13. Write a story about a group of water molecules that travels from the soil, through a plant and then into the atmosphere as water vapour.

Answers and sample responses are available in your digital formats.

LESSON 2.9 Review

2.9 Success criteria

Tick the column to indicate that you have completed the lesson and how well you think you have understood it using the traffic light system.

(**Green:** I understand; **Yellow:** I can do it with help; **Red:** I do not understand)

Lesson	Success criteria	Green	Yellow	Red
2.2	I can understand that our knowledge and understanding of cells has improved as a result of continued scientific investigation, human inventions and technological advancement. This work by scientists led to the creation of scientific theories such as the cell theory.			
2.3	I can identify different types of microscopes and understand their specific purposes. I can identify the key features of microscopes and describe how they work.			
2.4	I can recognise that organisms consist of a single cell or multiple cells.			
	I can identify key organelles within cells and describe their function.			
2.5	I can understand how to prepare a specimen for viewing with a microscope, including the use of dyes to highlight specific cell features.			
	I can record images using scientific drawing techniques.			
2.6	I can describe how cell shape and size (form) enable the functions of animal cells.			
2.7	I can identify and describe cells that are specialised in plants.			
2.8	I can describe the specialised transport systems in plants.			

learnon

Post-test	Topic 2 Post-test
eWorkbook	Topic 2 eWorkbook
Digital document	Key terms glossary

2.9 Activities

learnon

2.9 Review questions

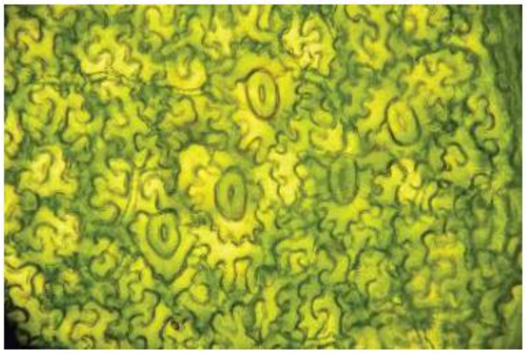
LEVEL 1	LEVEL 2	LEVEL 3
1, 3, 4, 6, 7, 10	2, 5, 8, 11	9, 12, 13, 14

Remember and understand

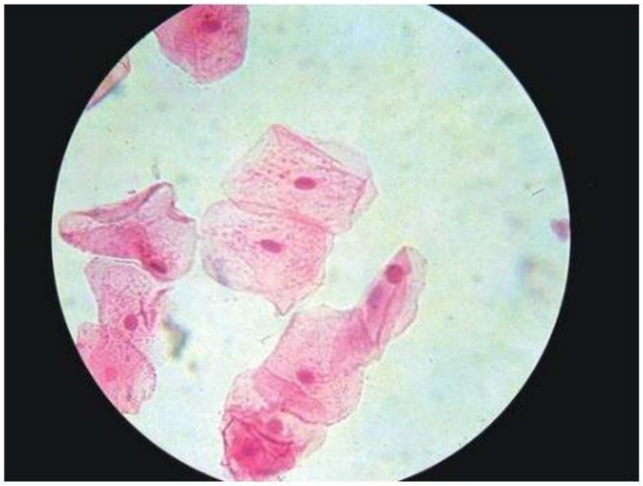
1. Copy and complete the table provided.

Cell feature	Plant cells	Animal cells	Fungal cells
Cell wall	✓	X	
Cytoplasm			
Cell membrane			
Chloroplast			
Nucleus			
Large vacuole			

2. Draw and label a typical plant cell and a typical animal cell.
3. **Identify** which of the following types of microscopes were used to take the photos shown. Give reasons for your answers.
   - Light microscope
   - Scanning electron microscope



4. Make a sketch of these human cheek cells.

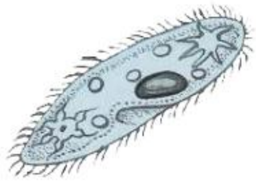


5. a. Match the following cell names to the diagrams provided.
   - *Euglena*
   - *Paramecium*
   - Onion epidermal cells
   - Nerve cell
   - Sperm cell
   - Guard cells
   - Root hair cell
   - Bacterium

   b. **State** which kingdom each of these cells belongs to.

a.

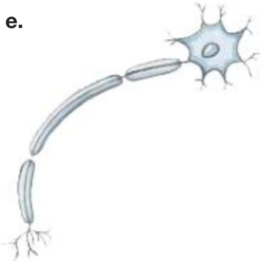
b.



c.

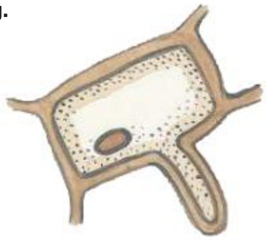
d.

e.



f.

g.



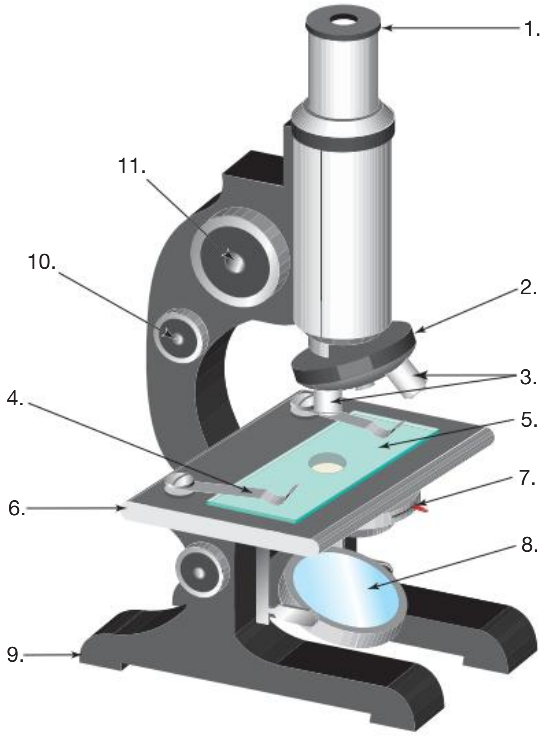
h.

Apply and analyse

6. a. Brainstorm as many 'cell'-related words as you can.

   b. Group or link words to make a concept, cluster or mind map.

7. **Construct** a Venn diagram to show the similarities and differences between:
   a. light microscopes and electron microscopes
   b. plant, animal and bacteria cells.
8. **Explain** the significance of the invention of the microscope in terms of how we see the world.
9. **Suggest** why the invention of microscopes led to the development of new scientific language and classifications.
10. Unscramble the words using the clues provided.
   a. Control centre of the cell SEUNCLU
   b. Surrounds the cell ERAMMBNE
   c. Contains cell sap OCVAUEL
   d. Part of the cell between the cell membrane and the nucleus CATOPLMYS
   e. Building blocks of all living things LELSC
   f. Living things ASMOGNIRS
11. **Identify** the parts of the microscope shown and use the code provided to find out the answer to this riddle.
   Code:
   O = revolving nose piece; U = objective lenses;
   S = coarse focus knob; K = fine focus knob;
   D = microscope slide; L = stage slide clip;
   C = base; O = mirror; L = iris adjustment;
   I = stage; M = eyepiece lens.



1	2	3	4	5	6	7	8	9	10	11

12. **Construct** a single bubble map to **identify**:
   a. types of plant cells
   b. types of animal cells
   c. scientists who have contributed to our knowledge of cells
   d. examples of body systems
   e. issues related to stem cells.

Evaluate and create

13. a. **Explain** why you think that cells have been described as 'living factories'.
    b. Think of a typical plant or animal cell. **List** of all the different parts and organelles. If the cell was a living factory, what might be the job of each listed part?
    c. Write a play to act out what happens in cells and perform it with others in your class. What sorts of things were easy to show? What sorts of things were hard to show? If you were to rewrite the play, what might you change and why?
    d. Convert the classroom into a giant cell! Take photos and then add information to them on a poster.
14. SI Students are exploring the use of biological stains on cells. They have access to some bacterial cells, some plant cells and animal cells, as well as the three biological stains listed.

Stain	Organelle stained
Crystal violet	Stains cell walls purple
Methylene blue	Stains nuclei blue
Eosin	Stains cell membranes pink

a. **State** what organelle is present in a plant cell but not in an animal cell.
b. **State** what organelle is present in a plant cell but not in a bacterial cell.

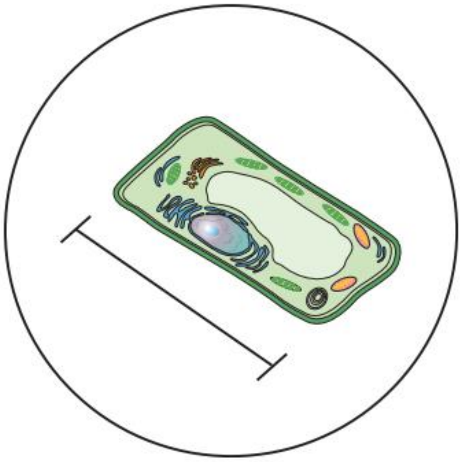
Unfortunately, the containers containing the cells are unlabelled and have been mixed up. No one can determine which is which.

c. **Outline** an experimental design that would allow you to determine which sample is which so that the correct labels can be applied.

The following observations were recorded.

Stain	Sample A	Sample B	Sample C
Crystal violet	Nothing was stained	Purple structure around outer wall of cell	Purple structure around outer wall of cell
Methylene blue	Blue organelle present in middle of cell	Nothing was stained	Blue organelle present in middle of cell
Eosin	Pink line outlining cell	Pink line outlining cell	Pink line outlining cell

d. From these results, which do you think is:
   i. sample A
   ii. sample B
   iii. sample C?



This diagram is a drawing of one of the cells taken during the experiment. The student forgot to add the scale (although they remembered to put in a scale bar).

e. If the field of view was 45 μm in diameter, approximately how big is this cell?
f. What type of cell is it most likely to be — plant, animal or bacteria — based on its structure? Give evidence to support your conclusion.

Answers and sample responses are available in your digital formats.

on To test your understanding and knowledge of this topic, go to your learnON title at www.jacplus.com.au and complete the **post-test**.

3 Systems

CONTENT DESCRIPTION

The structure of cells, tissues and organs in a plant and an animal organ system are related to their function; plant and animal organ systems enable survival of the organism (VC2S8U03)

Source: Victorian Curriculum F–10 Version 2.0

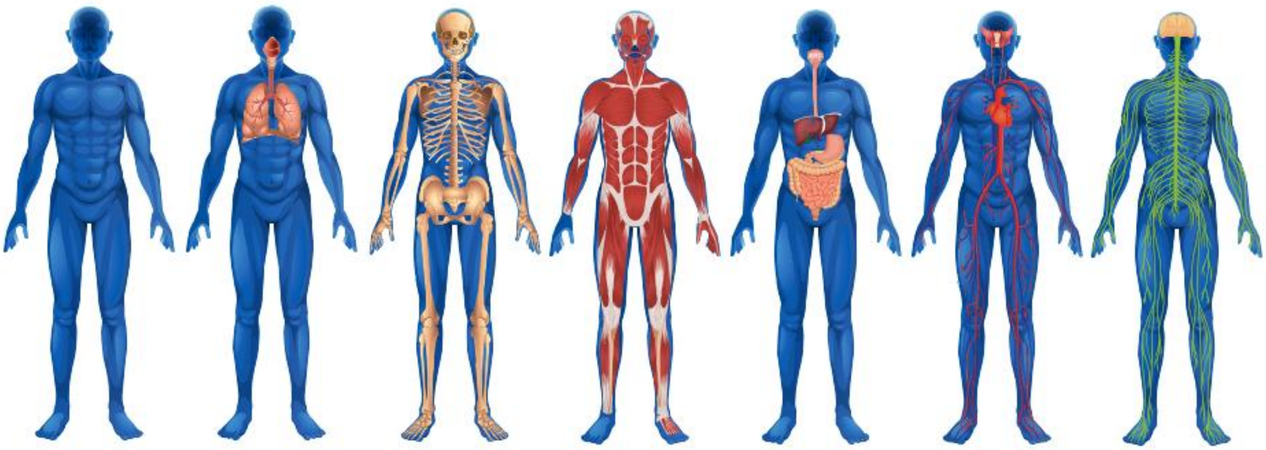
LESSON SEQUENCE

LESSON 3.1 Overview

3.1.1 Introduction

Throughout history, humans have asked questions about their bodies and how they work. Current knowledge has resulted from curiosity, imagination and persistence. Findings have shown that your body, like those of many other multicellular organisms, is very complex. It consists of body systems that work together to keep you alive. Each of your systems is made up of organs, which are made up of tissues, which are made up of cells — which cannot survive independently of each other. Differences in the structures of the cells, tissues and organs within these body systems suit them well for their specific functions. What questions do you have about your body and how it works?

FIGURE 3.1 In organisms, like humans, many body systems work together to keep them alive.



DISCUSSION

1. Why is it unusual for herbivores to have canine teeth?
2. Which human blood group is the most common?
3. What do intestinal villi in humans have in common with root hairs in plants?
4. How can burping give you heartburn?
5. What causes asthma?
6. What is the body's largest organ?
7. Why are red blood cells red?
8. What is special about cardiac muscle?

SCIENCE INQUIRY: Exploring human body systems

Our bodies are made up of several interconnected systems, such as the circulatory, respiratory, digestive and nervous systems. These systems work together to keep us alive and functioning. While we may look different on the outside, the internal structure of our body systems is remarkably similar across all humans. Each system plays a specific role but also depends on the others, creating a complex and fascinating network.

For example:
- The circulatory system transports oxygen and nutrients throughout the body.
- The respiratory system ensures that oxygen is exchanged for carbon dioxide.
- The digestive system breaks down food into nutrients that can be absorbed into the bloodstream.
- The nervous system coordinates actions and sends signals to the body through a network of nerves.

Understanding how these systems work together allows us to identify patterns, predict outcomes when one system is impacted and create models to better understand the complexity of human life.

1. How does physical activity affect heart rate over a short period?
2. How does holding your breath affect the amount of carbon dioxide in your exhaled air?
3. How do different types of food (e.g. protein, carbohydrates, fats) affect digestion time?

Investigable questions, reasoned predictions and hypotheses can be developed in guiding investigations to identify patterns, test relationships and analyse and evaluate scientific models (*VC2S8I01*)

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Pre-test	Topic 3 Pre-test
eWorkbooks	Topic 3 eWorkbook Student learning matrix
Practical investigation eLogbook	Topic 3 Practical investigation eLogbook
Digital document	Key terms glossary

LESSON 3.2 Driven by curiosity?

LEARNING INTENTION

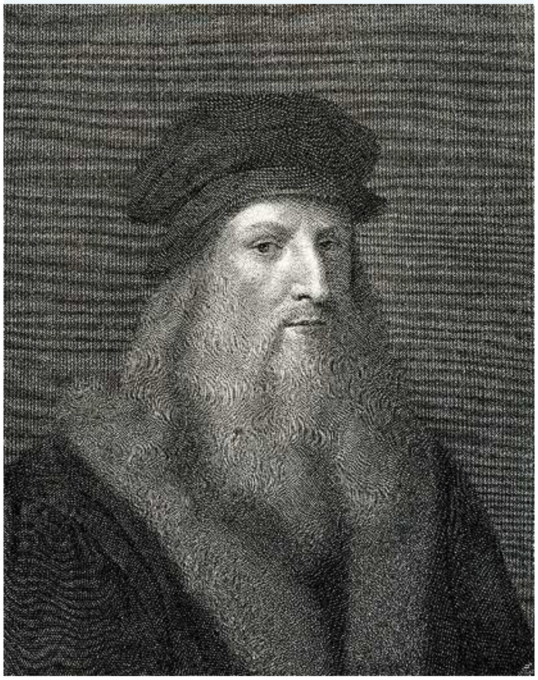
In this lesson you will:
- learn that scientific knowledge and understanding of the world change as new evidence becomes available
- provide examples of how our knowledge and understanding of the human body has changed over time.

3.2.1 Leonardo da Vinci ... intensely curious

Leonardo da Vinci was an Italian Renaissance artist, architect, engineer and scientist, with one of the best scientific minds of his time. He was intensely curious and painstaking in his observations. He used close observation, repeated testing and precise illustrations with explanatory notes. Using pen, chalk and brush, his scientific illustrations offered visual answers to mysteries that had escaped others for centuries. His volumes of amazing notes of scientific and technical observations in his handwritten scripts led to the birth of a new systematic and descriptive method of scientific study.

Leonardo da Vinci questioned everything. He may have been the most relentlessly curious man in history. He asked questions such as: Why do birds fly? Why can seashells be found in mountains? What is the origin of the wind and clouds? Why do people die? Where is the human soul found?

FIGURE 3.2 Leonardo da Vinci (1452–1519)



Dissecting, details and drawing

Leonardo's anatomical studies of human **muscles** and **bones** began around 1490. His exploration of embryology (study of the formation and development of an embryo) and cardiology (study of the heart and cardiovascular system) came later, with his astonishingly detailed image of a foetus within the womb (around 1510) providing details for obstetric surgery hundreds of years later. His observations were not just of bodies — later generations have been in awe of his sketches of inventions that were centuries ahead of their time.

An Italian biographer by the name of Paolo Giovio wrote the following about Leonardo da Vinci in the 1520s:

> *… in the medical faculty he learned to dissect the cadavers of criminals under inhuman, disgusting conditions … because he wanted [to examine and] to draw the different deflections and reflections of limbs and their dependence upon the nerves and the joints. This is why he paid attention to the forms of even very small organs, capillaries and hidden parts of the skeleton.*

FIGURE 3.3 Leonardo da Vinci spent hours amid rotting corpses to draw amazingly detailed observations of body structures.

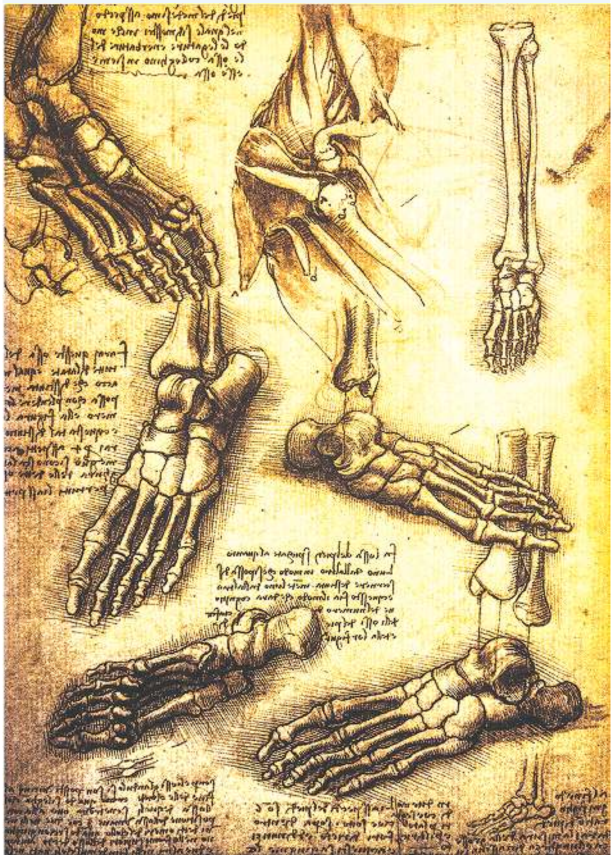
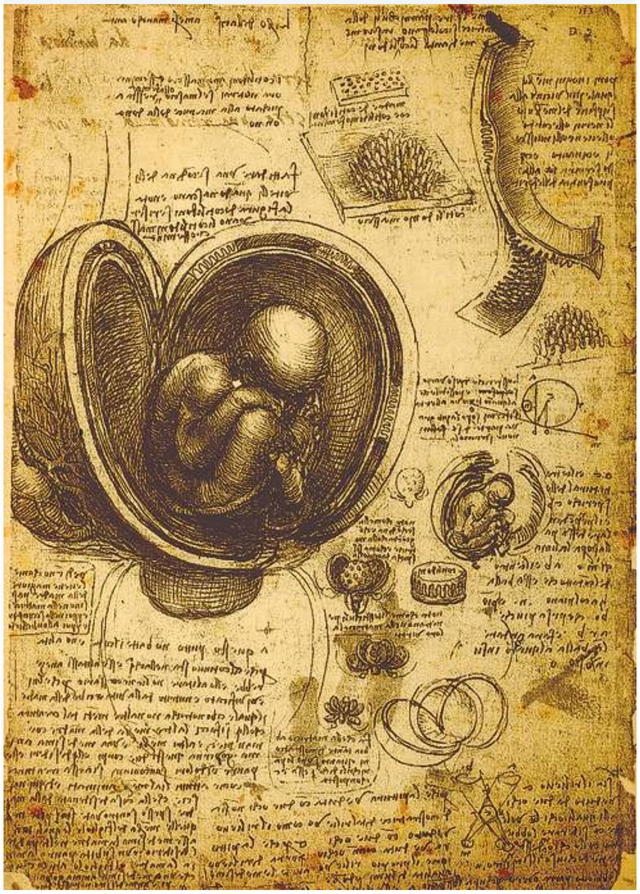


FIGURE 3.4 Leonardo's sketches of a fetus in the womb were completed between 1510 and 1513.



Challenging 'knowledge'

Knowledge of the human body was very different in Leonardo's day from what we accept today. The heart was thought to be made up of two chambers and its function to warm the blood, which was thought to be made in the liver. It was also thought that sperm were produced in the marrow of the spinal column and that the human soul may be located in the spine. Leonardo had questions he wanted to answer. He wanted to find out more. His investigations challenged the accepted knowledge of his day.

Visions and models

Leonardo also emphasised the significance of visual observations and model making — he believed that reality needed to be reconstructed before it could be represented. His models of hands and legs were used to reveal the structural relationships between different layers of arteries, muscles and bones. Leonardo also made a glass model of the heart and used water with different coloured dyes to trace its flow through the heart. His investigations linked anatomy (structure) and physiology (function).

Analogies are sometimes used to help people to connect new learning to previous knowledge. Leonardo used analogies to compare arteries in human bodies to 'underground rivers in the earth' and described the bursting of blood from a vein like 'water rushing out a burst vein of the earth'.

FIGURE 3.5 Leonardo was a master of detail with his sketches of body parts.

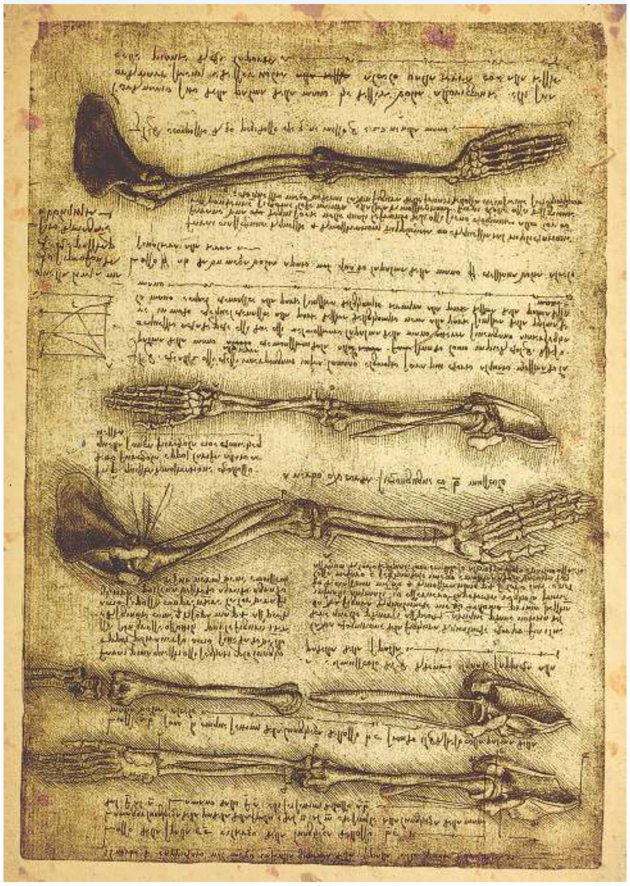
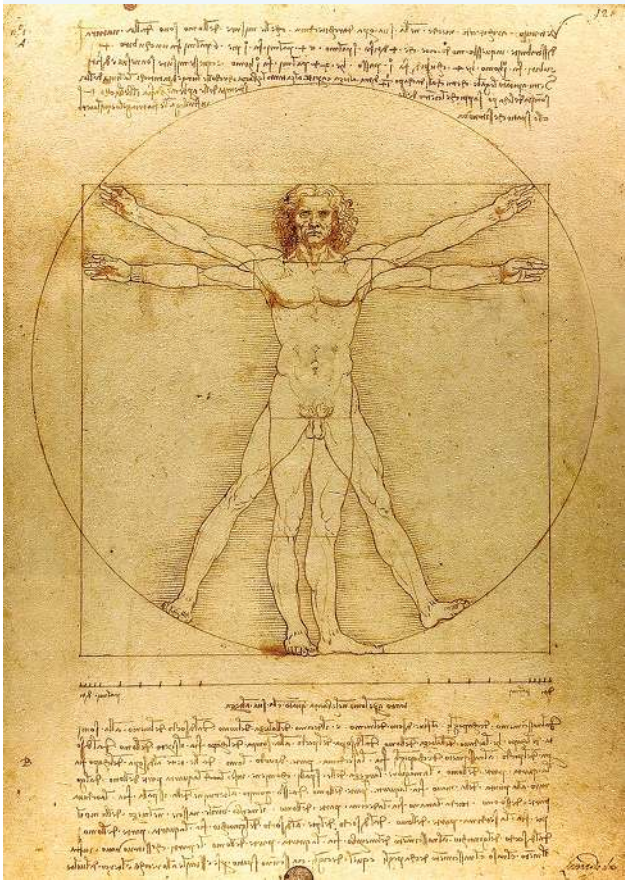


FIGURE 3.6 The Vitruvian Man drawing is one of Leonardo's most famous sketches.



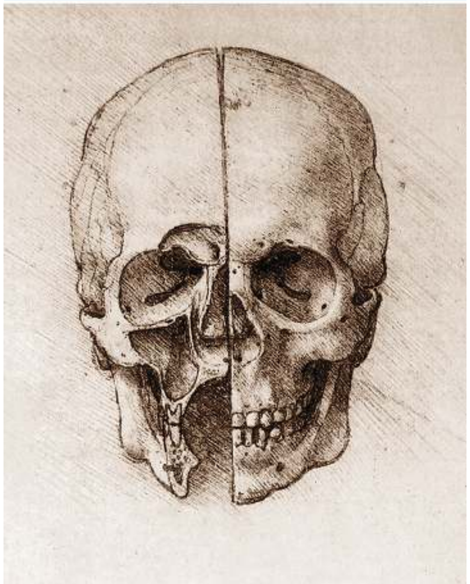
Leonardo's dissections led to changes in the knowledge and understanding of the structure and function of the heart, including that:

- the heart was a muscle
- the heart did not warm the blood
- the heart had four chambers
- left ventricle contractions were connected to the pulse in the wrist.

To locate cavities around the brain and cranium (figure 3.7), Leonardo used innovative techniques, such as injecting molten wax into them. Although Leonardo did not find the location of the human soul, his studies led him to the discovery that the brain and spine were connected.

Leonardo's curiosity, determination, creativity and persistence did more than make an amazing contribution to our current scientific knowledge of our bodies. These features also helped mould the way in which scientific frameworks were developed to structure our investigations to explore our questions.

FIGURE 3.7 Leonardo sketched this skull in 1489.



ACTIVITY: Questioning accepted knowledge

Explore how Leonardo da Vinci challenged the accepted scientific ideas of his time.

1. Why do you think people in Leonardo's time believed that the heart warmed the blood or that the human soul was located in the spine?
2. How did Leonardo's questions and investigations lead to changes in scientific knowledge?
3. Can you think of a modern scientific idea that might be challenged in the future?
4. In groups, identify a current scientific belief and discuss what tools or methods might be needed to challenge it.

3.2.2 Curiosity throughout time and space

Curiosity is one of the features of humans that has contributed to our survival. Some of this curiosity has been about the structure and function of our own bodies. Evidence of this curiosity is woven throughout history and is often found in art. While Leonardo da Vinci provides one example of curiosity driving a search to find out more, he is not the only example. Nor is human curiosity limited to the place or time in which you live.

Knowledge of the internal biology and physiological processes in art appears in rock paintings in caves in Australia that are thousands of years old (figure 3.8). Examples of Aboriginal or Torres Strait Islander Peoples' x-ray art provide evidence that this type of knowledge dates back more than 6000 years.

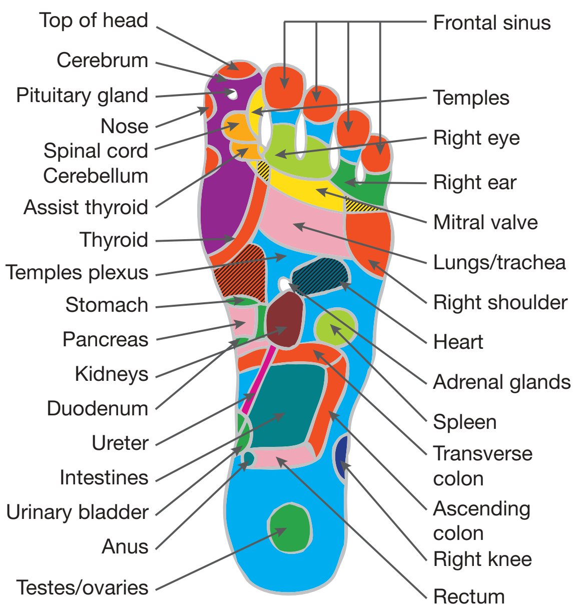
The culture and scientific knowledge of the times often determines the types of treatment given for various diseases of the human body. In medieval times, astrology played a key role in medicine and medical prognosis. It was believed that the 'movement of the heavens' could influence human physiology, with each part of the body being associated with a different astrological sign. An image of the 'Zodiac Man' (figure 3.9) in the medical texts of the time was used to assist practitioners in their medical treatments. It was based on astrology and the position of the Moon, and provided practitioners guidance for the correct time to do certain procedures.

Chinese traditional medicine is an ancient medical system that has been practised for over 5000 years and applies understanding of the laws and patterns of nature to the human body. It views health as the changing flow throughout the body of vital energy (*qi*) that, if hindered, can lead to illness. Acupressure is an application of this theory that aims to release blocked energy by stimulating specific points along the body's energy channels (figure 3.10).

FIGURE 3.8 An 'x-ray style' rock painting figure from Kakadu National Park, Northern Territory, Australia

FIGURE 3.9 The 'Zodiac Man' provided advice on when to perform certain medical procedures.

FIGURE 3.10 An example of an acupressure reflexology chart



Scientists are curious

Scientists are also often driven by the thirst to find answers to their questions. With increased advances in technology and knowledge, the answers to these questions often result in even more questions.

Compared with the situation in Leonardo's day, there are now an amazing number of different types of careers that involve investigations, explorations and applications of science to the human body. Australian scientists are involved in medical research and intervention, and development of medical equipment that helps with our understanding of our **body systems**.

3.2.3 Australian scientists: creative inventors and explorers

Australian scientists have made significant contributions to medical discoveries and inventions. Howard Florey and his team discovered how penicillin could be extracted, purified and produced to be used as an antibiotic to help fight bacterial infections. Barry Marshall and Robin Warren showed that a certain type of bacteria caused stomach ulcers that could be treated with antibiotics. Professor Graeme Clark and his team were involved in the invention of an effective 'bionic ear'. Dr Fiona Wood pioneered a new treatment for burns in her development of 'spray-on skin' that uses the patient's own skin cells. Professor Ian Frazer developed the world's first vaccine against cervical cancer.

DISCUSSION

Research and report on the role of Ngangkari healers, their traditional health systems and how they work with people and medical professionals.

SCIENCE AS A HUMAN ENDEAVOUR: The bionic ear

The cochlear implant, also known as the bionic ear, has allowed some people with inner-ear problems to hear sound for the first time. When deafness results from serious inner-ear damage, no sounds are heard at all. Normal hearing aids, which make sound louder, do not help in these cases because the cochlea cannot detect the vibrations. However, the cochlear implant can often help by changing sound energy from outside the ear into electrical signals that can be sent to the brain.

FIGURE 3.11 An enlarged x-ray of the cochlear implant, showing the experimental electrode array inside

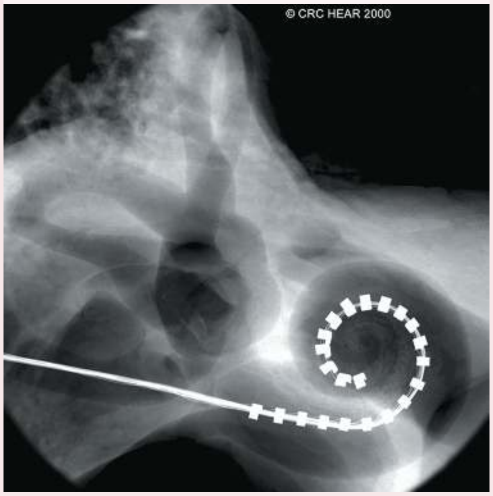
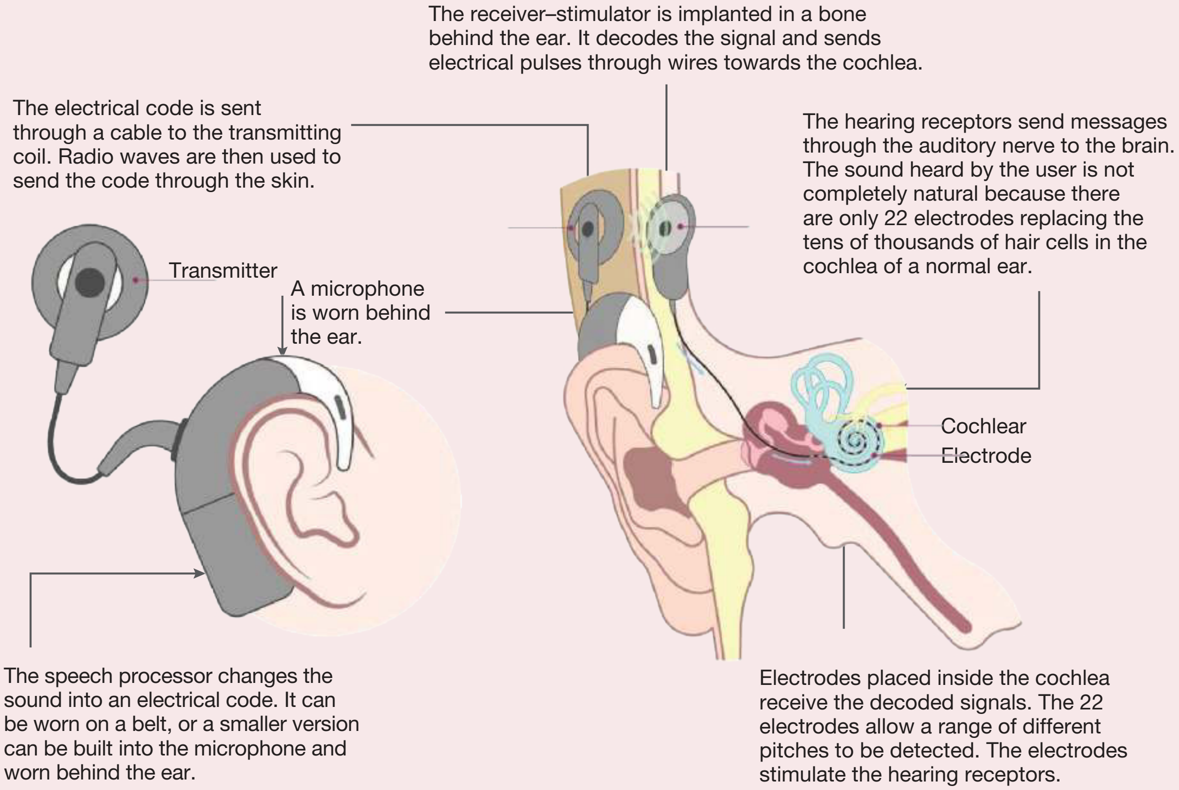


FIGURE 3.12 How a cochlear implant works



1. Imagine you are a scientist working on improving cochlear implants. What kinds of features or advancements would you try to add to make the implants even more helpful for people with hearing loss?
2. Why do you think it is important for scientists and doctors to continue researching and improving technologies such as the cochlear implant? How can these advancements benefit people and society as a whole?

Proposed scientific responses to socio-scientific issues impact on society and may involve ethical, environmental, social and economic considerations (VC2S8H03)

3.2 Activities

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3.2 Quick quiz on	3.2 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 11	4, 6, 7	5, 8, 9, 10

Remember and understand

1. a. **State** whether the following statements are true or false.
   Leonardo da Vinci's dissections led to changes in the knowledge and understanding:

Statement	True or false?
i. of the structure and function of the heart	
ii. in that the heart was a muscle with three chambers that warmed the blood	
iii. in that the heart's left ventricle contractions were connected to the pulse in the wrist	
iv. in that the location of the human soul was in the spine.	

   b. Rewrite any false responses.
2. Match the Australian scientist with their scientific contribution.

Australian scientist	Scientific contribution
a. Barry Marshall	A. I developed the world's first vaccine against cervical cancer.
b. Fiona Wood	B. I was involved in discovering how penicillin could be extracted, purified and produced to be used as an antibiotic to help fight bacterial infections.
c. Graeme Clark	C. I pioneered a new treatment for burns using 'spray-on skin' that uses the patient's own skin cells.
d. Howard Florey	D. I was involved in the invention of an effective 'bionic ear'.
e. Ian Frazer	E. Robin Warren and I showed that a certain type of bacteria caused stomach ulcers that could be treated with antibiotics.

3. **Distinguish** between anatomy and physiology.

Apply and analyse

4. Imagine you were alive in the medieval times. **Suggest** why astrology played a key role in medicine and medical prognosis.
5. **Suggest** how scientific understanding of human body systems can determine how we respond to public health issues such as the 2009 swine flu pandemic and the 2020 coronavirus pandemic.
6. **Construct** an interesting story about Leonardo da Vinci's anatomical studies.
7. **Analyse** how scientific knowledge and understanding of the human body have changed over time. Provide examples of how new evidence has led to changes in our understanding.
8. Create a brochure of the cochlear implant, showing its benefits to prospective users.

Evaluate and create

9. SI a. Do you believe that acupressure should be available as a medical treatment? **Justify** your response.
   b. Does scientific knowledge support your stance? **Explain**.
10. SI **Evaluate** the analogies used by Leonardo da Vinci to describe arteries and the bursting of blood from a vein. Incorporate current scientific knowledge into your evaluation.
11. SI **Evaluate** Leonardo da Vinci's sketches and analyse their impact. Then create a tree diagram to illustrate how the sketches have influenced modern science.

Answers and sample responses are available in your digital formats.

LESSON 3.3 Working together

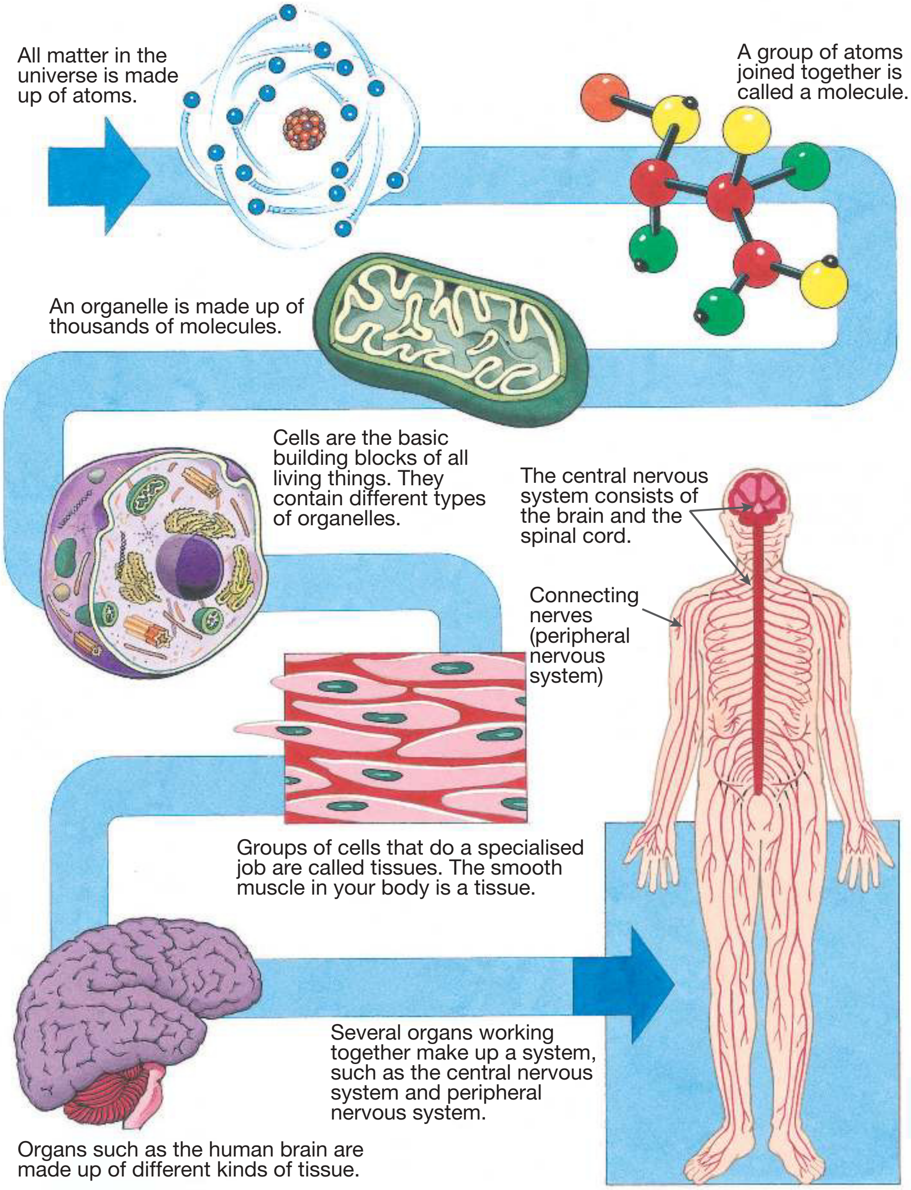
LEARNING INTENTION

In this lesson you will provide examples of how the different body systems — made up of specialised organs, tissues and cells — work together to keep multicellular organisms alive.

3.3.1 The building blocks of life

Like all matter in the universe, you are made up of **atoms**. Collections of atoms make up **molecules**; molecules make up **organelles**, which make up **cells**, which make up **tissues**, which make up **organs**, which make up systems, which make up you. This progression is shown in figure 3.13.

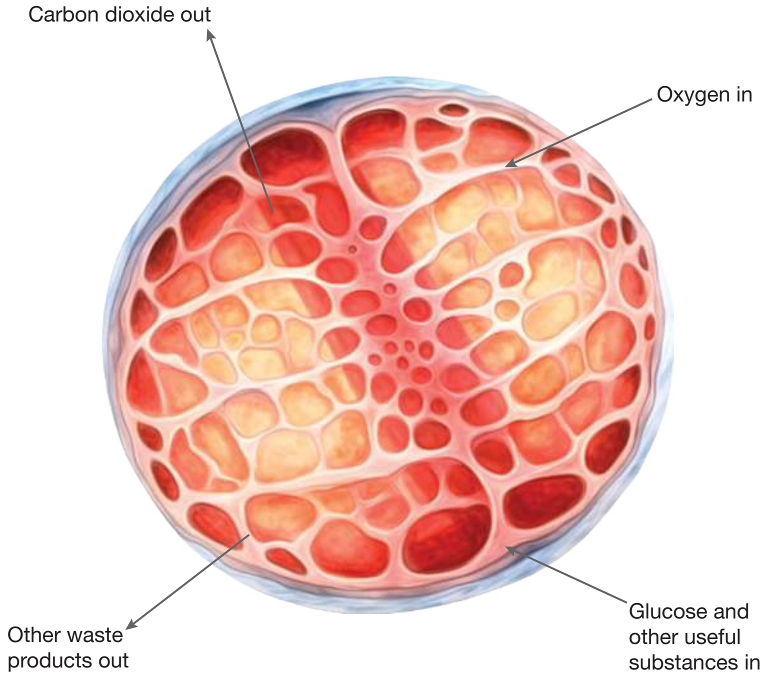
FIGURE 3.13 The building blocks of life



3.3.2 All alone? Independent!

Unicellular organisms are made up of only one cell that must do all of the jobs that are required to keep the organism alive. These single-celled organisms are small enough that essential substances (e.g. oxygen) and wastes (e.g. carbon dioxide) can be exchanged with their environment through simple **diffusion**.

FIGURE 3.14 Useful substances (e.g. oxygen) can move into cells, and wastes (e.g. carbon dioxide) can move out through a process called diffusion.



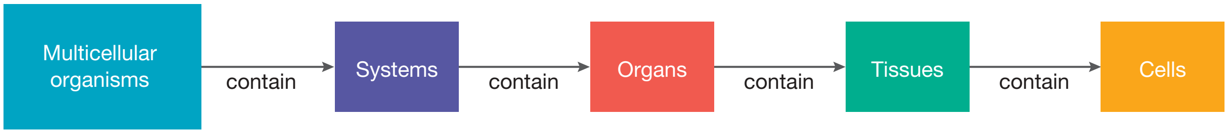
3.3.3 One of many? Better get organised!

Like other multicellular organisms, you are made up of many cells. These cells cannot survive independently of each other. They depend on each other and work together. Working together requires organisation.

Pattern, order and organisation

Multicellular organisms are made up of a number of body systems that work together to keep them alive. Body systems are made up of organs, which are made up of tissues, which are made up of particular types of cells.

FIGURE 3.15 Organisation of systems



Cells

Within each cell there are structures called organelles. Each organelle has a particular job to do. Mitochondria, for example, are organelles in which the chemical energy in glucose is transformed into energy that our cells can use.

Multicellular organisms are made up of many different types of cells, each with a different job to do. Although these cells may have similar basic structures, they differ in size, shape, and in the number and types of organelles they contain. The different make-up of different types of cells and structures within them makes them well suited to their function.

Tissues

Groups of similar cells that perform a specialised job are called tissues. Muscle tissue contains cells with many mitochondria so that the energy requirements of the tissue can be met. Nerve tissue consists of a network of nerve cells with extensions to help carry messages throughout your body. Figure 3.16 shows some examples of tissues that make up your body, what they look like and what their main functions are.

FIGURE 3.16 There are different types of tissues, each with structural features that suit them to their function.

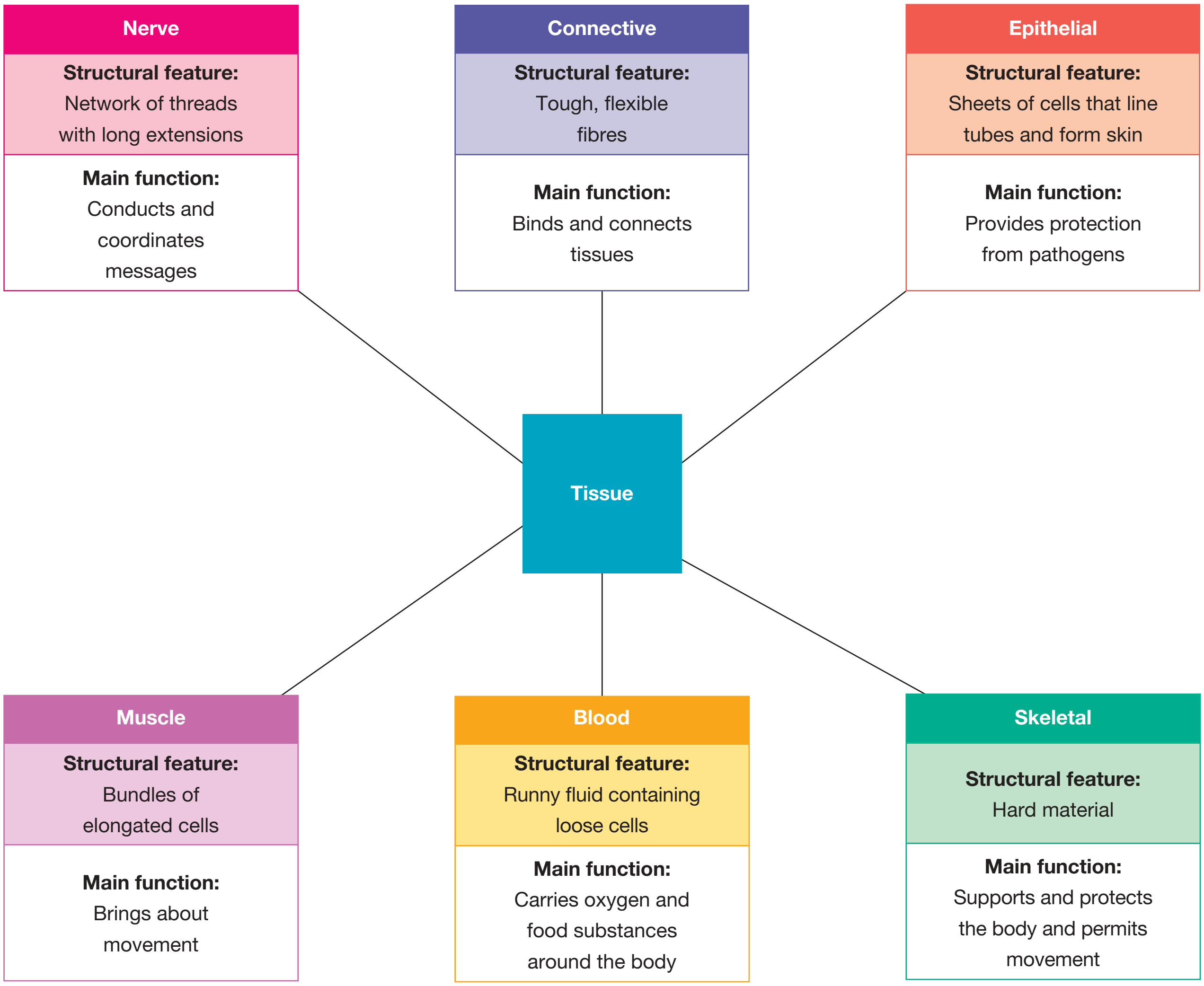
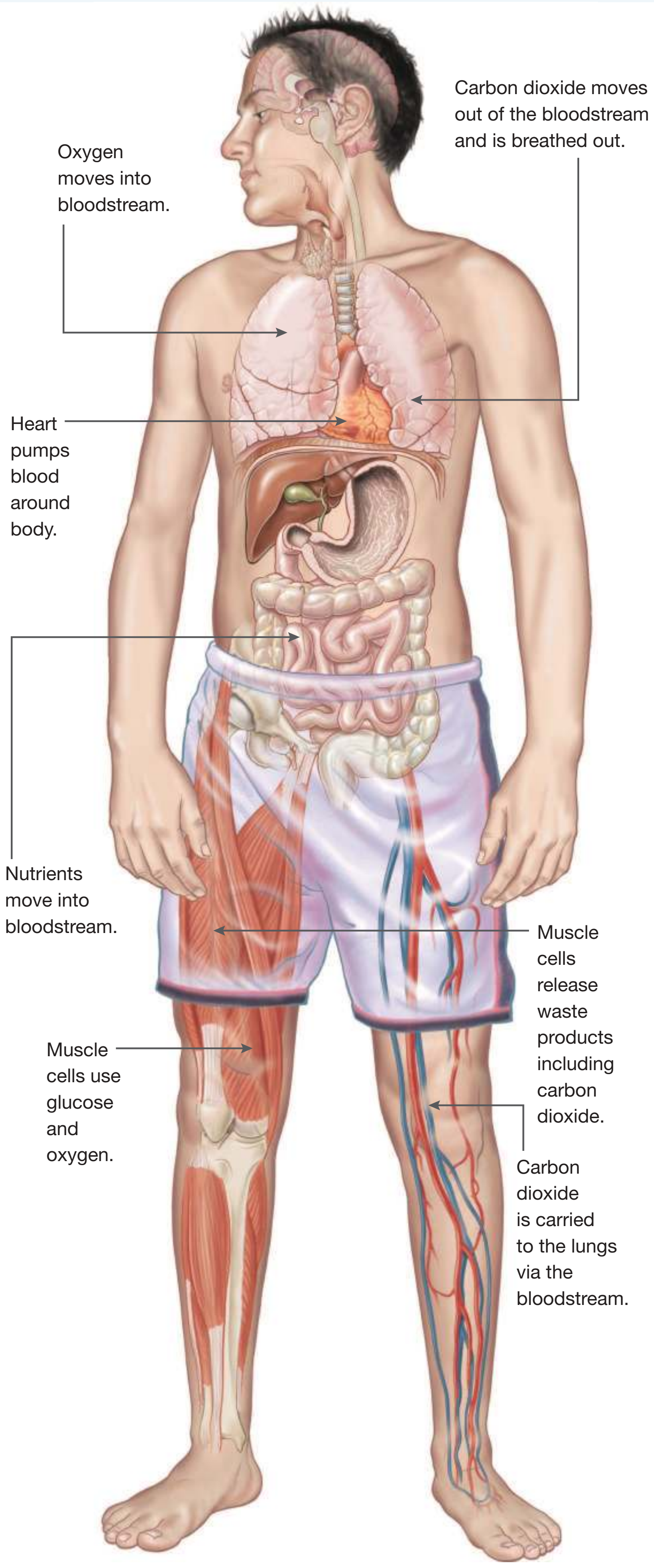


FIGURE 3.17 You are made up of many different body systems that contain organs that work together to keep you alive.



Organs

Organs are made up of one or more different kinds of tissue and perform one (or sometimes more) main function or job. Examples of your organs include:

- brain
- stomach
- lungs
- heart
- skin
- kidneys.

Systems

Multicellular organisms contain organised systems of organs that work together to perform specialised functions. Table 3.1 provides examples of some of your systems, some organs within them and their main functions.

TABLE 3.1 Examples of systems and their main functions

Name of system	Organs in system	Main functions
Digestive system	Stomach, intestine, liver, pancreas, gall bladder	To digest and absorb food
Respiratory system	Trachea and lungs	To take in oxygen and remove carbon dioxide
Circulatory system	Heart and blood vessels	To carry oxygen and food around the body
Excretory system	Kidneys, bladder, liver	To remove poisonous waste substances
Sensory system	Eyes, ears, nose	To detect and respond to stimuli
Nervous system	Brain and spinal cord	To conduct messages between body parts
Musculoskeletal system	Muscles and skeleton	To support and move the body
Reproductive system	Testes and ovaries	To produce offspring

3.3.4 Systems need to work together

Body systems within multicellular organisms work together to keep them alive. For example, cells need energy to survive. A process called **cellular respiration** breaks down glucose to release energy in a form that your cells can then use. This process also requires oxygen and produces carbon dioxide, a waste product. Your digestive, circulatory, respiratory and excretory systems work together to provide your cells with nutrients and oxygen, and to remove wastes such as carbon dioxide.

Respiratory system

The **respiratory system** is responsible for getting oxygen into your body (figure 3.18) and carbon dioxide out (figure 3.19). This occurs when you inhale (breathe in) and exhale (breathe out).

FIGURE 3.18 Your respiratory system is involved in getting oxygen into your body.

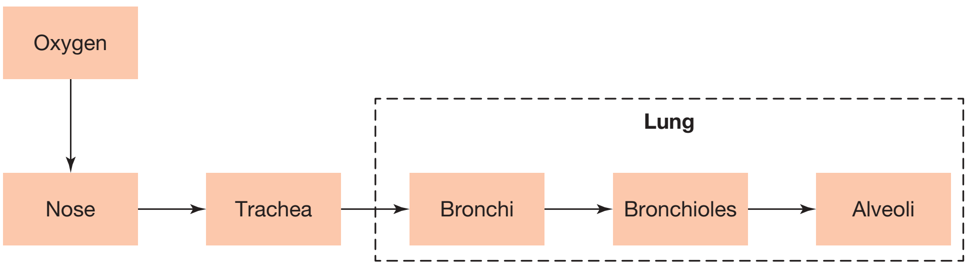
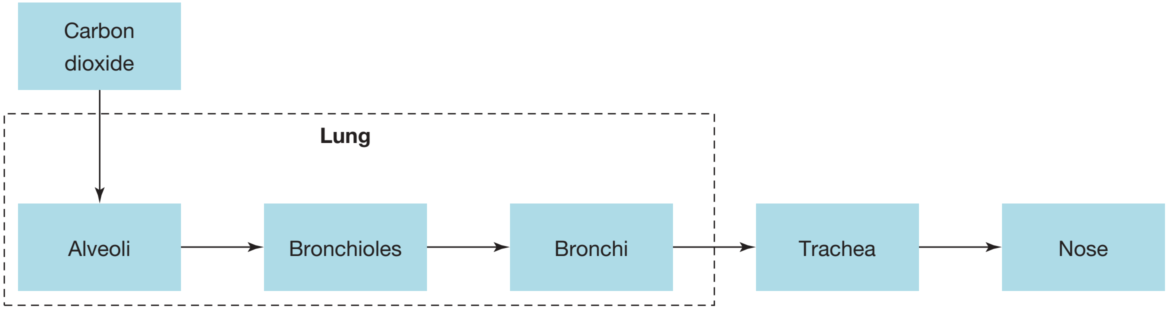


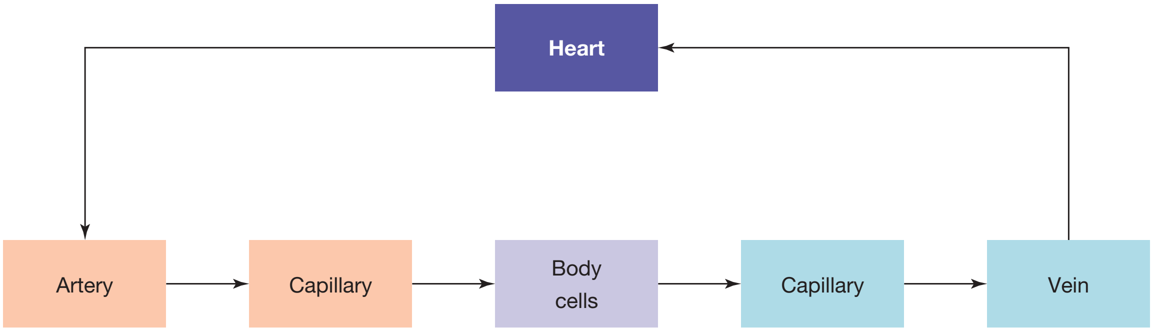
FIGURE 3.19 Your respiratory system is involved in getting carbon dioxide out of your body.



Circulatory system

The **circulatory system** is responsible for transporting oxygen and nutrients to your body's cells, and wastes such as carbon dioxide away from them. This involves **blood cells** that are transported in your **blood vessels** and **heart**. The major types of blood vessels are **arteries**, which transport blood from your heart; **capillaries**, through which materials are exchanged with cells; and **veins**, which transport blood back to the heart. This is seen in figure 3.20.

FIGURE 3.20 Your circulatory system is involved in transporting blood cells in blood vessels to and from your body cells and your heart.



Digestive and excretory systems

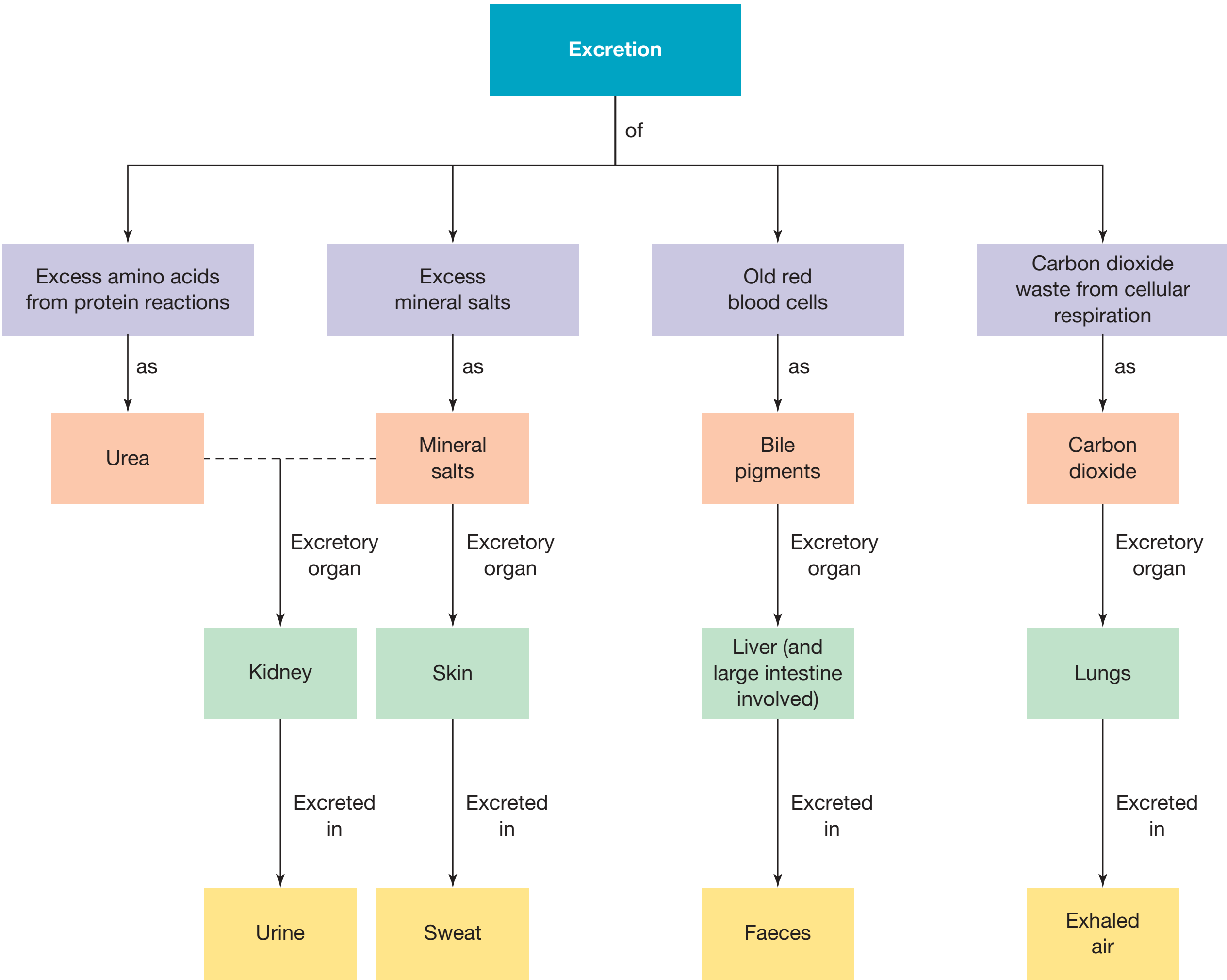
The **digestive system** plays a key role in supplying your body with the nutrients it requires to function effectively. You ingest food, digest it, then egest (excrete) it. Your digestive system is involved in breaking food down so nutrients are small enough to be transported to, and used by, your cells.

The **excretory system** removes waste products from a variety of chemical reactions that your body needs to stay alive. The main organs of your excretory system are your skin, lungs, liver and kidneys. Your skin excretes salts and water as sweat, and your lungs excrete carbon dioxide when you breathe out. Your liver is involved in breaking down toxins for excretion. Your kidneys are involved in excreting the used waste products of chemical reactions (e.g. urea) and any other chemicals that may be in excess (including water), so that a balance within your blood is maintained. Some of the organs of the excretory system are shown in the flowchart in figure 3.21.

Other body systems

The **musculoskeletal system** consists of both your bones and various types of muscles throughout your body. Bones and muscles provide both support and protection for your organs. While the **reproductive systems** of males and females contain different organs in each sex, they both play a key role in the continuation of our species. Other systems such as the **nervous system** and **endocrine system** are also involved in coordinating and regulating processes in your body. You will find out more about these later in your studies.

FIGURE 3.21 Different organs in your excretory system are involved in the removal of different types of wastes.



ACTIVITY: Apply knowledge of the systems to real-life scenarios

1. Imagine someone's kidneys stop functioning properly. What might happen to their body if waste products and excess water are not excreted?
2. How might this scenario impact other systems in the body, such as the circulatory or respiratory systems?
3. In small groups, brainstorm potential medical interventions for kidney failure (e.g. dialysis or kidney transplants) and present them to the class.

INVESTIGATION 3.1

Mapping your organs

Aim

To draw a diagram to map out the positions and shapes of some human body organs

Materials

- large sheets of paper (e.g. butcher paper)
- pencils and marker pens

- sticky tape
- scissors
- optional: light coloured material, sewing thread and needle (or stapler or craft glue), 'stuffing', various other bright coloured materials

Method

1. Use the sticky tape to join the paper together so that it is the size of a student's body outline.
2. One member of the team lies down on the paper with their arms away from their body.
3. Another team member carefully draws (about 5 cm away from their body) an outline of their partner's body.
   - Once the outline is drawn, the person on the paper can join the rest of the team for the remainder of the activity.
   - As a team, decide where in the body outline the following organs are located: heart, lungs, small intestine, nose, oesophagus, liver, stomach, ears, kidney, large intestine, pancreas, eyes, bladder, brain, trachea, mouth.
   - Once the location of each organ has been agreed upon, discuss their shape and size.
4. Once consensus is reached within the group, draw each of these organs onto the paper body outline.
   - Compare your diagram to reference materials to judge its accuracy.
5. Using these references as a guide, use different coloured pens to draw in more accurate organ shapes, sizes or locations onto your paper body outline.
   Optional: Use the final version of your organ body outline as a pattern to make human body organ stuffed toys or a human body organ blanket.

Results

How accurate was your team's first attempt at drawing the body organ outline?

a. Which organs were located correctly and which were not?
b. How closely did your team's estimate of shape and size compare to that referenced for each organ?

Discussion

1. Identify the system to which each of the organs on your outline belongs.
2. As an individual learner, identify which organs had a size, shape and location that you expected, and which did not.

Conclusion

Summarise the findings for this investigation.

DISCUSSION

Did you take a particular role in this team? Assess how well you supported other members of your team.

In pairs, apply your understanding of the structure and function of two different body systems by writing ten trivial pursuit questions (with answers) for each of your selected systems.

3.3 Activities

learnon

3.3 Quick quiz on	3.3 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 4, 10, 11	5, 6, 7, 8, 9, 12, 17	13, 14, 15, 16, 18, 19

Remember and understand

1. a. **Identify** whether the following statements are true or false.

Statement	True or false?
i. All living things consist of at least one cell.	
ii. Unicellular organisms are made up of only one cell that must do all of the jobs that are required to keep the organism alive.	
iii. Multicellular organisms are made up of different types of cells that cannot survive independently of each other so need to work together.	
iv. Multicellular organisms are made up of different types of cells, each with different jobs to do.	
v. The differences in the size and shape of different types of cells and the structures within them make them well suited to their specific function.	
vi. Cellular respiration involves production of glucose.	
vii. The respiratory system takes oxygen into your body and removes carbon dioxide from your body.	
viii. The circulatory system transports carbon dioxide and nutrients to your body cells, and transports wastes such as oxygen away from them.	
ix. Arteries transport blood to your heart and veins transport blood away from your heart.	
x. Your kidneys, skin, liver and lungs all play a role in removing wastes from your body.	

   b. Rewrite any false responses.
2. **Name** a feature that organisms have in common with other matter in the universe.
3. Order the following from most complex to least complex: molecules, organelles, organs, multicellular organisms, systems, tissues, atoms, cells.
4. What am I? **Identify** the most appropriate term by matching it to the corresponding description in the table shown.

Term	Description
a. Tissue	A. A structure within a cell with a specific job to do
b. Organ	B. A collection of similar cells that perform a specific function
c. System	C. Different types of tissues grouped together to perform a specific function
d. Organelle	D. Different organs working together to perform a specialised function to keep an organism alive

5. **List** six:
   a. types of tissues
   b. examples of organs
   c. systems.

6. **Name** two organs in the:
   a. respiratory system
   b. circulatory system
   c. digestive system.
7. **Name** an example of an organelle and state its function.
8. Match the type of tissue with its function in the table shown.

Tissue	Function
a. Blood	A. Conducts and coordinates messages
b. Connective tissue	B. Brings about movement
c. Muscle tissue	C. Binds and connects tissues
d. Nervous tissue	D. Lines tubes and spaces, and forms skin
e. Skeletal tissue	E. Carries oxygen and food substances around the body

9. Match the system with its organs in the table shown.

System	Organs
a. Circulatory system	A. Liver, kidney, skin, lungs
b. Digestive system	B. Lungs, trachea
c. Excretory system	C. Stomach, liver, gall bladder, intestines, pancreas
d. Nervous system	D. Heart, blood vessels
e. Respiratory system	E. Brain, spinal cord

10. **Describe** two ways in which unicellular organisms differ from multicellular organisms.
11. **Explain** why cells in muscle tissue contain many mitochondria.

Apply and analyse

12. **Compare** the structure of nerve cells and muscle cells in a multicellular organism. **Discuss** how their differences in size and shape affect their roles within the organism.
13. Using diagrams or models, illustrate the relationship between:
    a. atoms, molecules, organelles and cells
    b. cells, tissues, organs and systems.
14. **Suggest** how scientific understanding of human body systems can help us to diagnose and treat a variety of illnesses.
15. **Construct** Venn diagrams to compare the:
    a. digestive system and respiratory system
    b. respiratory system and circulatory system
    c. excretory system and reproductive system
    d. circulatory system and excretory system.

Evaluate and create

16. Think about how the digestive system, respiratory system and circulatory system work together to keep your body healthy. Give examples to **explain** why this teamwork is important.
17. SI a. Select a body system and **construct** a PMI chart on how its structural features assist it in achieving its function.
    b. **Propose** ways in which the body system could be improved.
    c. **Justify** your proposed improvements.
18. SI a. Design and **construct** a model of one of the following human body systems: respiratory, excretory, digestive or circulatory.
    b. **Construct** a PMI chart on the accuracy of your model in effectively describing the structure and function of your selected body system.
    c. **Identify** three ways in which it could be improved.

19. SI Select one of the following questions to investigate and present your findings as a labelled model(s), informative animation, picture story book or interesting class presentation. For each question, select animal (i), (ii) or (iii) to compare it with a human.
   a. In which ways are the respiratory systems of (i) a fish, (ii) an earthworm OR (iii) an insect and a human similar, and how are they different?
   b. In which ways are the digestive systems of (i) a starfish, (ii) a snake OR (iii) a bird and a human similar, and how are they different?
   c. In which ways are the circulatory systems of (i) an insect, (ii) a frog OR (iii) a snake and a human similar, and how are they different?

Answers and sample responses are available in your digital formats.

LESSON 3.4 Digestive system — break it down

LEARNING INTENTION

In this lesson you will describe the structure and function of the digestive system.

3.4.1 The gastrointestinal tract

The **gastrointestinal tract** (or digestive tract or **alimentary canal**) may be considered as your main digestive highway (figure 3.22). It consists of a long tube with coils, large caverns and thin passageways. Other organs that provide chemicals to break down food or absorb nutrients are attached to the gastrointestinal tract. The gastrointestinal tract begins at the mouth and ends at the anus, where waste products are removed.

FIGURE 3.22 The human digestive system in 3D

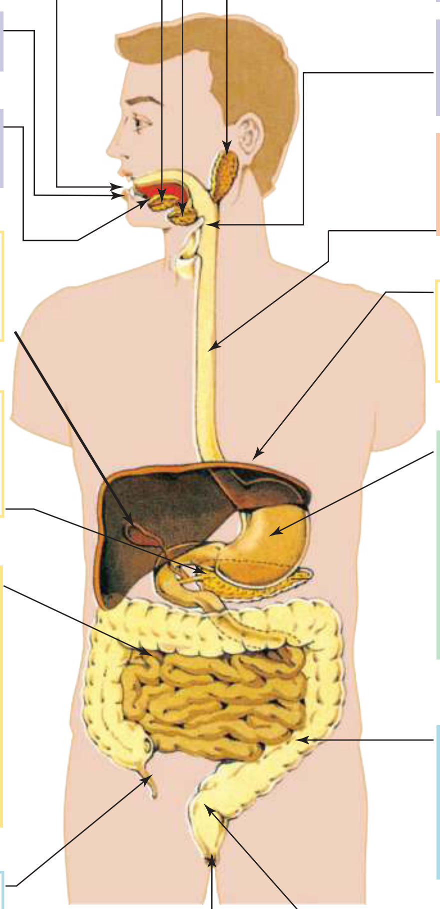
3.4.2 Digestion

Digestion involves the breaking down of food so that the nutrients it contains can be absorbed into your blood and carried to each cell in your body.

Five key processes are important in supplying nutrients to your cells. These are:
- ingestion — taking food into your body
- mechanical digestion
- chemical digestion
- absorption of the broken-down food into your cells
- assimilation — converting the broken-down food into chemicals in your cells.

FIGURE 3.23 The human digestive system 2D

In → Mouth → Oesophagus → Stomach → Small intestine → Large intestine → Anus → Out



Teeth. Used to bite and chew your food to break it down into smaller pieces.

Mouth. Food and saliva are mixed; teeth mechanically break food into smaller pieces.

Tongue. Involved in rolling food into a round ball (bolus) that is then pushed to the back of your mouth to be swallowed.

Gall bladder. Bile made in the liver is stored here; bile breaks up fats into droplets small enough to be transported to the rest of the body.

Pancreas. Makes pancreatic juice, which is alkaline (base dissolved in water) so it neutralises the stomach acid. Enzymes that break down proteins, fats and carbohydrates are also made here.

Small intestine. A tube about 6 m long. Food moves through it by peristalsis. The small intestine makes enzymes that complete the digestion process. The cells in the wall of the small intestine release over 5 litres of mucus and water each day. It is in the small intestine that nutrients from now almost totally digested food are absorbed into your bloodstream. The blood then carries the nutrients to all of the cells of your body.

Appendix. Plays no part in digestion in humans. However, it is believed to play a role in fighting some diseases.

Anus. The faeces pass through here when you go to the toilet.

Salivary glands. Make about 1.5 litres of saliva each day. Saliva contains enzymes that begin breaking down starch in food.

Epiglottis. A flap of tissue closes off your trachea (windpipe) so that food doesn't go down to your lungs and cause you to choke.

Oesophagus. Also known as the food-pipe or gullet. It carries the food to the stomach, using involuntary muscular contractions known as peristalsis.

Liver. The largest internal organ. It makes bile, which breaks down fats; controls blood sugar; destroys poisons; and stores vitamin A, vitamin D and iron.

Stomach. A temporary food storage area, which can expand to hold between 2 and 4 L of food. Muscle movements in the stomach wall mix the food with gastric juice, which helps to break down proteins. The stomach also contains dilute hydrochloric acid, which kills germs and provides a suitable environment for protein digestion.

Large intestine (colon). Undigested material passes into the large intestine. As the material is pushed through it by peristalsis, water, salts and vitamins are absorbed so that they can be reused by the body.

Rectum. The final part of the large intestine. This is where the faeces are stored.

3.4.3 Mechanical and chemical digestion

Mechanical digestion (also known as physical digestion) involves physically breaking down food into smaller pieces. Most of this process takes place in your **mouth** when your **teeth** bite, tear, crush and grind food. **Chemical digestion** involves the use of chemicals called **enzymes** to break down food into small molecules.

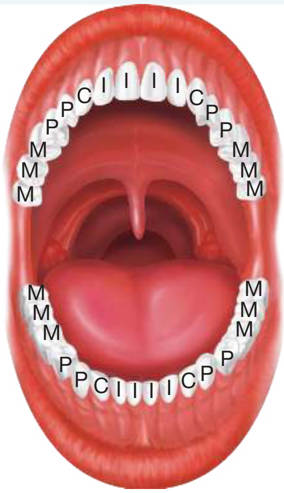
Mouth

You ingest food, digest it, then egest it. The whole process of digestion starts with you taking food into your mouth. Enzymes (such as amylases) in your **saliva** are secreted by your **salivary glands** and begin the process of chemical digestion of some carbohydrates. Your teeth physically break down food in a process called mechanical digestion, then your tongue rolls the food into a slimy, slippery ball-shape called a **bolus**.

Look at those teeth!

In many vertebrates, mechanical digestion begins with the teeth. There are four main types of teeth in humans, each type with a different function and position in your mouth, as shown in figure 3.24. Your teeth are your very own set of cutlery.

FIGURE 3.24 The four different types of human teeth

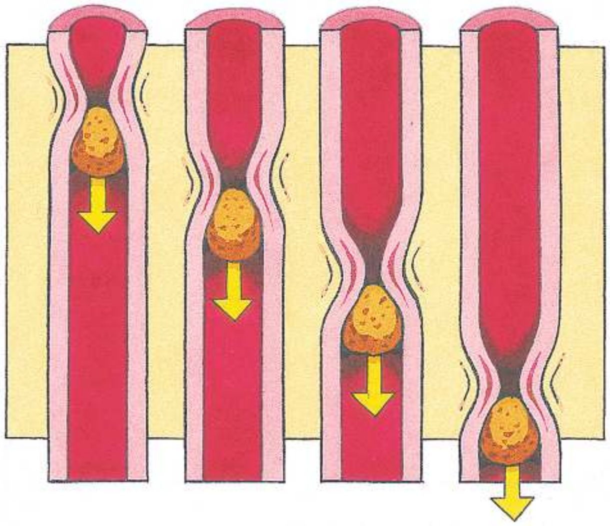


Type of teeth	Structure	Description
Incisors (I)		Shape: Spade-shaped with straight, sharp edge Function: Cutting and biting food Location: Found at the front of your mouth
Canines (C)		Shape: Sharp points and fang-like Function: Shearing and tearing through food Location: Found on each side of incisors
Premolars (P)		Shape: Generally two pointed cusps Function: Roll, grind and crush food Location: Found between the canines and molars
Molars (M)		Shape: Have between three and five cusps that fit together with those in the upper and lower jaws Function: Grind food Location: Found at the back of your mouth

Oesophagus to stomach

The bolus is then pushed through your **oesophagus** by muscular contractions known as **peristalsis**. From here it is transported to your **stomach** for temporary storage and further digestion.

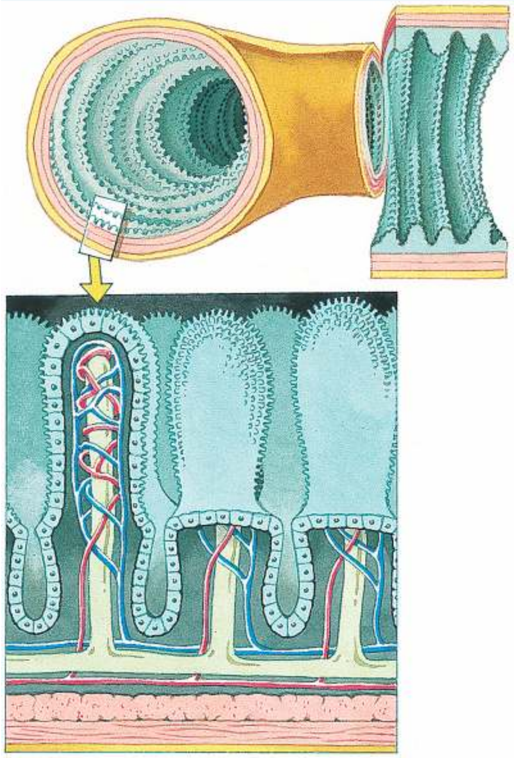
FIGURE 3.25 Partly digested food is forced along the oesophagus by peristalsis — a wave of involuntary muscular contractions.



Stomach to small intestine

Once the food gets from your stomach to your **small intestine**, more enzymes (including amylases, proteases and lipases) break it down into molecules that can be absorbed into your body. The **absorption** of these **nutrient** molecules occurs through finger-shaped **villi** in the small intestine (figure 3.26). Villi are shaped like fingers to maximise surface area, which increases the efficiency of nutrient absorption into the surrounding capillaries. Capillaries are tiny blood vessels that transport the nutrients from the villi into your bloodstream. Once absorbed into the capillaries (of your circulatory system), these nutrients are transported to cells in the body that need them.

FIGURE 3.26 Most nutrient absorption happens in the ileum, the last section of the small intestine, where finger-like villi maximise surface area. Undigested material moves to the large intestine before excretion.



Large intestine

On its way through the gastrointestinal tract, undigested food moves from the small intestine to the **colon** of the **large intestine**. It is here that water and any other required essential nutrients still remaining in the food mass may be absorbed into your body. **Vitamin D** manufactured by bacteria living within this part of the digestive system is also absorbed. Any undigested food, such as the **cellulose** cell walls of plants (which we refer to as fibre), also accumulates here and adds bulk to the undigested food mass.

The **rectum** is the final part of the large intestine, where the faeces is stored before being excreted through the **anus** as waste.

ACTIVITY: Exploring enzymes and their roles

Enzymes, such as amylases, proteases and lipases, break food into smaller molecules.

1. Why do you think the body uses different enzymes for different types of food (e.g. carbohydrates, proteins and fats)?
2. What might happen if one type of enzyme was missing or did not work properly?
3. In groups, create a 'job description' for each enzyme, outlining its role in the digestive process.

3.4.4 The liver and pancreas

Liver

Your liver is an extremely important organ with many key roles. One of these is the production of **bile**, which is transported to your **gall bladder** via the bile ducts to be stored until it is needed. Bile is transported from the gall bladder to the small intestine, where it breaks down **lipids** such as fats and oils.

Pancreas

Enzymes such as **lipases**, **amylases** and **proteases**, which break down lipids, carbohydrates and proteins respectively, are made by the **pancreas** and secreted into the small intestine to chemically digest these components of food.

3.4.5 Do we need them?

There are some body organs that, if they become diseased or damaged, can be removed through surgery and the patient recovers to live a normal, healthy life.

Within the digestive system, the **gall bladder**, which, as you have learned, stores bile from the liver for use in fat digestion, can become diseased and therefore requires removal. Without the gall bladder, the liver will continue to produce bile and secrete it directly into the small intestine. This results in a continual release of small volumes of bile, rather than storing it and releasing large volumes when required, which, in turn, can lead to difficulties digesting fat and even diarrhoea or constipation. These effects are usually short-lived while the body adapts to the changes.

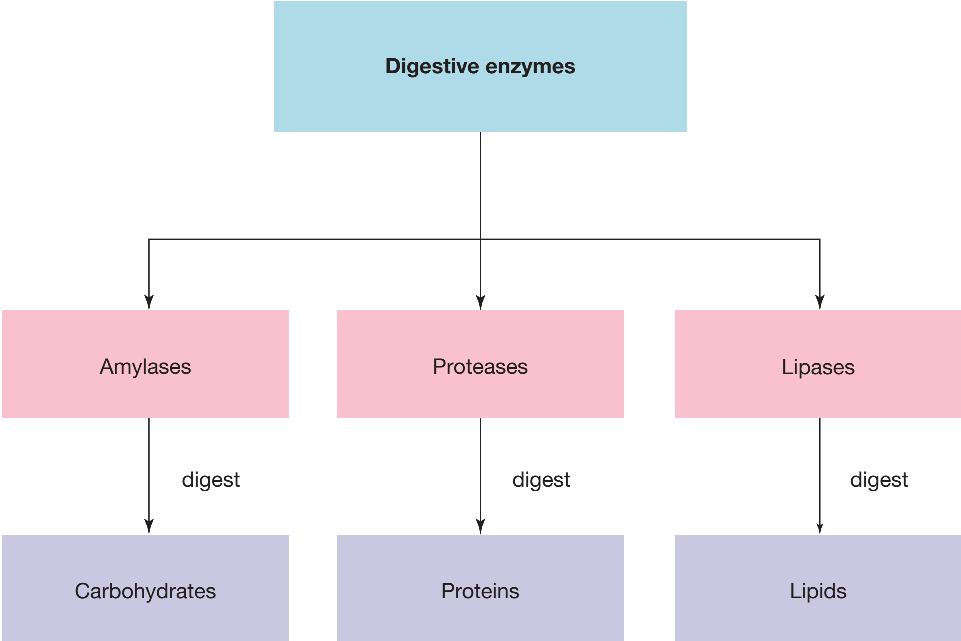
The **appendix** can also be removed by surgery if it becomes diseased or damaged. In some animals, such as cows, which feed almost entirely on grass, the appendix is large and contains a lot of bacteria that help digest cellulose in plant cell walls. This makes it essential to their digestive system. Recent research suggests that in humans, the appendix helps maintain healthy gut bacteria and supports the immune system. However, its removal does not appear to cause any significant complications.

3.4.6 Enzymes

Chemical digestion is usually assisted by compounds called enzymes that increase the rate of the chemical reactions. Without enzymes, a single meal could take many years to break down. Mechanical digestion increases the rate of chemical digestion because it increases the surface area of the food particles. This exposes more of the food surface to the digestive chemicals and enzymes.

Chemical digestion begins in your mouth, where enzymes in saliva begin to break down some of the carbohydrates in the food that you eat.

FIGURE 3.27 Certain molecules are broken down by specific enzymes.



Fat stuff

Breaking down lipids, such as fats and oils, is hard work! Because lipids are insoluble in water, they tend to clump together into large blobs. Bile assists in solving this problem, as it helps to **emulsify** or separate the lipids so the lipase enzymes can gain access to them and do their job. This is an example of bile and lipase working together.

FIGURE 3.28 Bile emulsifies fat so that lipases can break it down.

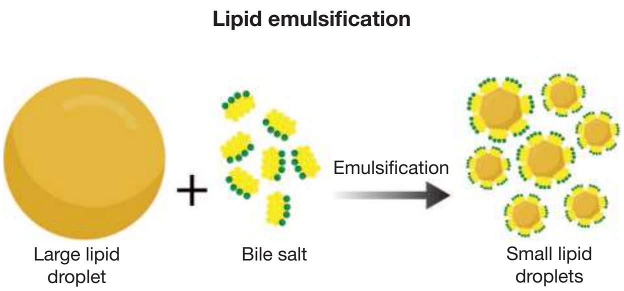
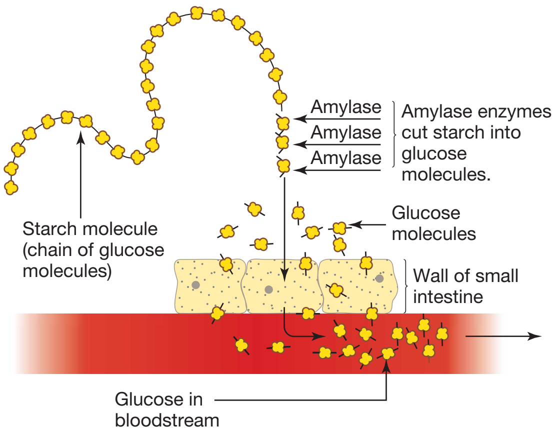


FIGURE 3.29 Amylases in the saliva and stomach break starch down into glucose molecules.



Not too hot!

Enzymes are made of protein. That is why it is important that they are not overheated. If they are too hot, they can become **denatured**. It's the same as cooking an egg — once they are denatured, they can't go back to how they were before, so they can't work as enzymes anymore. Different enzymes operate best within specific temperature ranges.

INVESTIGATION 3.2

Does temperature affect enzymes?

Aim

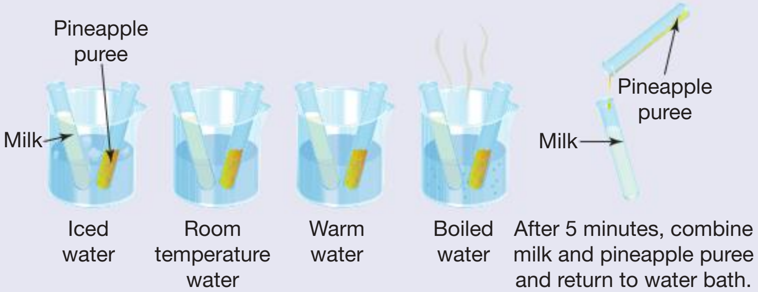
To investigate the effect of temperature on enzyme activity

Materials

- 4 beakers
- 8 test tubes
- milk
- 4 thermometers
- fresh pineapple puree (Fresh pineapple can be pureed using a food processor. If fresh pineapple is not available, use junket powder or a junket tablet dissolved in 10 mL water.)

Method

1. Add water to the beakers so they are two-thirds full. Use cold tap water and ice for beaker 1, cold tap water for beaker 2, hot tap water for beaker 3 and boiling water (from a kettle) for beaker 4. These are the 'water baths'.
2. Half-fill four test tubes with milk and put one test tube in each water bath.
3. Place one teaspoon of fresh pineapple puree (or 1 mL of junket solution dissolved in 10 mL of water) in the other four test tubes. Put one of these test tubes in each water bath.
4. Allow the test tubes to stand in the water baths for at least 5 minutes.
5. For each water bath, pour the fresh pineapple puree into the milk and stir briefly.



Results

1. Copy the table provided and complete it with your results. Remember to include a title for your table.

Water bath	Temp. of milk and pineapple mix (°C)	Time taken to set (minutes)

2. Quickly record the temperature of the milk and pineapple mixture and then allow it to stand undisturbed. The mixture will eventually set. Record the time taken to set. If the milk has not set after 15 minutes, record the time as 15+.

Discussion

1. Pineapple juice and junket contain an enzyme that causes a protein in milk (casein) to undergo a chemical reaction and change texture; that is why the milk sets. At what temperature did the enzyme work best?
2. Did the enzyme work well at very high temperatures? Explain your answer.
3. Which variables were controlled in this experiment?
4. Do you think that the same results would be obtained if tinned pineapple puree was used instead of fresh pineapple puree? Explain your answer.
5. Identify the strengths and limitations of this investigation, and suggest ways to improve it.
6. Propose a research question about enzymes that could be investigated.

Conclusion

Summarise the findings for this investigation.

3.4.7 Personal explosions

Well, excuse me! Have you burped or passed wind recently? Have you had diarrhoea or vomited? These 'personal explosions' are related to the processing of nutrients by your body.

Burping, or belching, occurs when air is swallowed or sucked in. This may happen when you talk while you eat, eat or drink too quickly or drink fizzy drinks (such as those with carbon dioxide gas dissolved in them). When you eat too fast and don't chew your food enough, more acid can be produced in your stomach. When you burp, some of this acid can rise up into your oesophagus, resulting in a burning sensation called **heartburn**.

Flatulence refers to the release of gases when you 'pass wind' through your anus. These gases are produced by bacteria in your large intestine. The odour and composition of the gases depend on the foods you have eaten and the amount of air you have swallowed.

Diarrhoea is the excessive discharge of watery faeces. It occurs when the muscles of the large intestine contract more quickly than normal, usually in an effort to rid your body of an infection. As a result, the undigested food moves through too rapidly for enough water to be absorbed into your body.

Green vomit? Messages from your stomach wall travel to the 'vomiting centre' of your brain, resulting in the forceful ejection of your stomach contents (and occasionally also contents from your small intestine). **Vomiting** can be caused by eating or drinking too much, anxiety, infections or chemicals that irritate your stomach wall. If the vomit is green, it may be due to the colour of food ingested or the presence of bile.

INVESTIGATION 3.3

Making a burp model

Aim

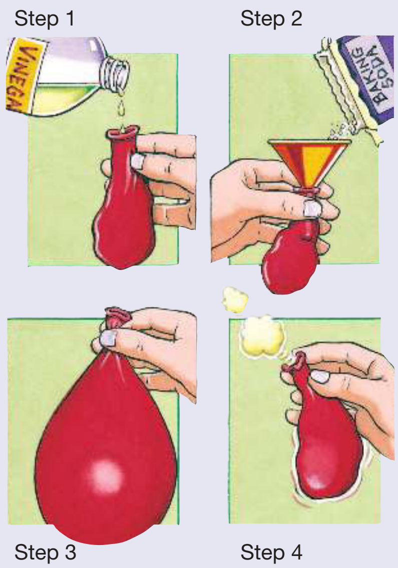
To construct a burp model, and to design and construct a model that demonstrates the functioning of a process related to the digestive system

Materials

- vinegar
- baking soda
- medium/large balloon
- funnel

Method

1. Pour a small amount of vinegar into the bottom of the balloon 'stomach'.
2. Add some baking soda to the balloon 'stomach' using a funnel.
3. Using your fingers, pinch the balloon closed at its neck.
4. Watch as your 'stomach' expands with gas.
5. Unpinch the top of the balloon (or 'oesophagus/food tube') to release the gas (or burp).
6. Try to make your model sound like the real thing!



Results

1. Summarise your observations in a flowchart that includes labelled diagrams or digital/photographic images.
2. Select an organ belonging to an animal of your choice. Find out more about the structure and function of your selected organ and how it does its job. Summarise your findings.
   - Design and make a simple model (such as the one used for this experiment) to show how your selected organ achieves its function, or what happens when something goes wrong.
3. Summarise your design plans and labelled diagrams or digital images into an advertising brochure or digital multimedia advertisement.

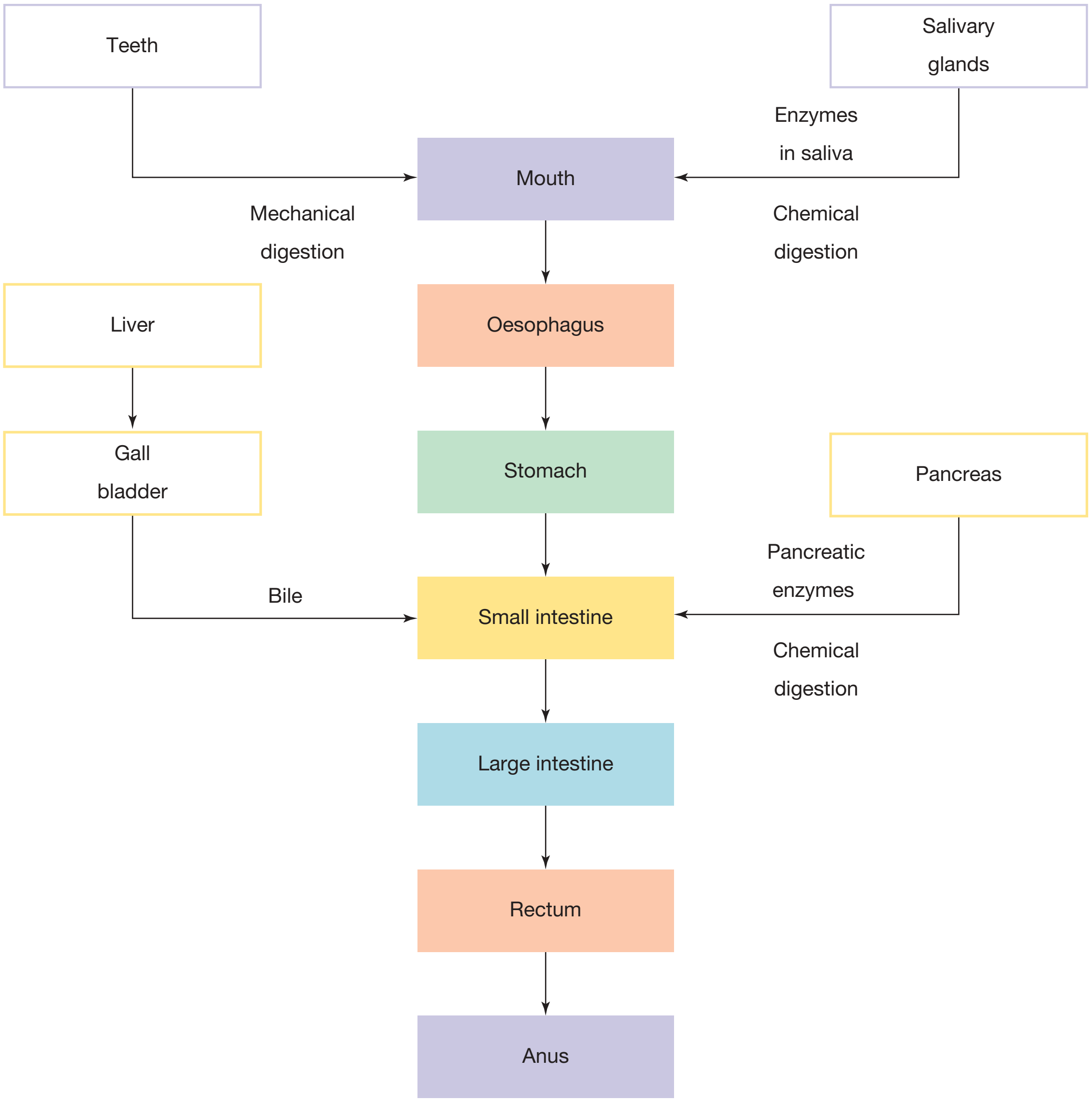
Discussion

Comment on the challenges you experienced during the design and construction of your model, and suggest ways that you could overcome these if you were to do it again.

Conclusion

Summarise the findings for this investigation.

FIGURE 3.30 Summary: Digestion occurs in a systematic and organised manner.



3.4 Activities

learnon

3.4 Quick quiz on	3.4 Exercise

■ LEVEL 1	■ LEVEL 2	■ LEVEL 3
1, 2, 4, 6, 9, 10, 11, 12, 14	3, 5, 7, 15, 17, 20	8, 13, 16, 18, 19, 21

Remember and understand

1. a. **State** whether the following statements are true or false.

Statement	True or false?
i. Mechanical digestion occurs when chemicals in your body react with food to break it down.	
ii. Ingestion involves taking food into your body, whereas digestion involves breaking food down.	
iii. Many enzymes have names that end with the suffix 'ase'.	
iv. 'Bolus' is the term used to describe the muscular contractions that push food down your oesophagus to your stomach.	
v. Plant cell walls make up much of the fibre that accumulates in our large intestines.	
vi. The process of denaturing enzymes kills them.	
vii. Proteases are enzymes that break down carbohydrates.	
viii. Heartburn can be caused by acid from your stomach rising up your oesophagus.	
ix. Flatulence refers to the release of gases when you 'pass wind' through your anus.	
x. The green colour of vomit may suggest the presence of bile, which has been produced by the gall bladder.	

   b. Rewrite any false responses.

2. Match the types of teeth with their specific function in the table shown.

Types of teeth	Function
a. Canines	A. Biting and cutting food
b. Incisors	B. Grinding and crushing food
c. Molars and premolars	C. Tearing and grasping food

3. **Identify** the different types of teeth as being one of the following: incisors, canines, premolars or molars.

a.

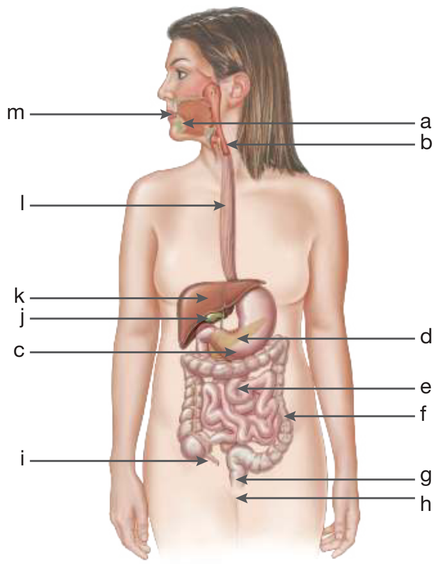

b.


c.


d.


4. Order the following organs into the correct sequence: stomach, large intestine, oesophagus, anus, mouth, small intestine.

5. **Identify** the organs (a–m) in the figure given.



6. Match the organ with its function in the table shown.

Organ	Function
a. Gall bladder	A. Where the breakdown of starch and protein is finished and fat breakdown occurs
b. Large intestine	B. Temporary storage of food and where protein digestion begins
c. Liver	C. Tube that takes food from mouth to stomach
d. Oesophagus	D. Stores undigested food and waste while bacteria make some vitamins
e. Pancreas	E. Stores faeces
f. Rectum	F. Makes enzymes used in the small intestine
g. Small intestine	G. Makes bile, stores glycogen and breaks down toxins
h. Stomach	H. Stores bile made in the liver until needed in the small intestine

7. **State** the name of the:
   a. type of digestion that involves enzymes
   b. enzymes that break down fats
   c. enzymes that break down proteins
   d. substances that enzymes act on.
8. **List** the five key processes that are important in the supply of nutrients to your cells.
9. **Explain** why it is important to break down food that we eat.
10. **Describe** what happens to enzymes when they get too hot.
11. **Describe** the process of peristalsis and suggest why it occurs.
12. **Suggest** why it is necessary to drink fluids when you suffer from diarrhoea.
13. **Describe** the relationship between:
    a. teeth and mechanical digestion
    b. the pancreas and the small intestine
    c. the liver, gall bladder and the small intestine
    d. the villi, small intestine and capillaries
    e. bile, lipases and fats.

Apply and analyse

14. Which teeth are used to:
    a. bite into a pear
    b. crush and grind nuts?
15. **Suggest** how you can still swallow food if you are positioned upside down.

16. Take a small piece of bread into your mouth. Although at first you don't taste much, after a while, it may taste sweet. Suggest why.
17. **Construct** Venn diagrams to compare:
    a. mechanical and chemical digestion
    b. lipases and proteases
    c. the small intestine and large intestine.
18. Use information in this lesson and other resources to relate structural features to the functions of the following parts of the digestive system.

Part of digestive system	Structural features	Function
Oesophagus		
Stomach		
Small intestine		
Villi		
Large intestine		

Evaluate and create

19. SI When cows burp, they release methane gas into the air. This gas is believed to be one of the major causes of global warming. It has been suggested that cows could be responsible for about 20 per cent of the methane in the atmosphere. **Construct** an experiment that could be used to test the claim that cows contribute to increased methane gas in the atmosphere.
20. SI **Construct** an investigation to test the following hypotheses:
    - Fresh pineapple results in a faster enzyme reaction than canned pineapple.
    - The length of time that pineapple puree is kept in ice affects the rate of enzyme reaction.
    - Different coloured junket tablets result in different rates of enzyme reaction.
21. SI a. Imagine that you are either a cheese and tomato sandwich or a hamburger.
    b. **List** the ingredients of the food you chose in part a.
    c. **Identify** what happens (and where) to each of these ingredients when eaten.
    d. **Construct** a flowchart to show the process of digestion in the human body, including events and locations.
    e. Use this information to write a story in either a cartoon or picture book format.

Answers and sample responses are available in your digital formats.

LESSON 3.5 Digestive endeavours

LEARNING INTENTION

In this lesson you will give examples of ways in which science and technology have contributed to scientific knowledge and understanding of your digestive system, and have led to related improved medical treatments.

3.5.1 The digestive system as a scientific human endeavour

When your digestive system is healthy, it actively works along, busily doing its job without you even having to think about it. But sometimes, things can go wrong. For example, tooth decay, gum disease, intestinal polyps and a variety of digestive system diseases may result in some form of intervention. Research and developments in science and technology have not only increased our understanding and knowledge about our digestive system, but have also led to improved medical treatments to help us when things go wrong.

3.5.2 Do you look after your teeth?

It is very important to look after your teeth. Damaged or missing teeth can make it difficult for you to chew your food properly and therefore may affect digestion of foods.

Ouch! Does your tooth hurt?

Your teeth can decay when bacteria in your mouth turn sugar from your food into acid. This acid can 'eat' a hole in your tooth enamel and dentine. Once this hole reaches a nerve, you get a toothache. Figure 3.31 shows the structure of a tooth and where decay usually occurs — at the top of large back teeth and at the side, where one tooth touches another.

How many times do you clean your teeth each day?

If you don't brush your teeth and floss between them regularly (at least once a day), they can become covered with a thin film of food, saliva and bacteria. This is called plaque. As this plaque rots, it causes your gums to swell and bleed. This is known as gum disease (also known as **periodontal disease** or **gingivitis**).

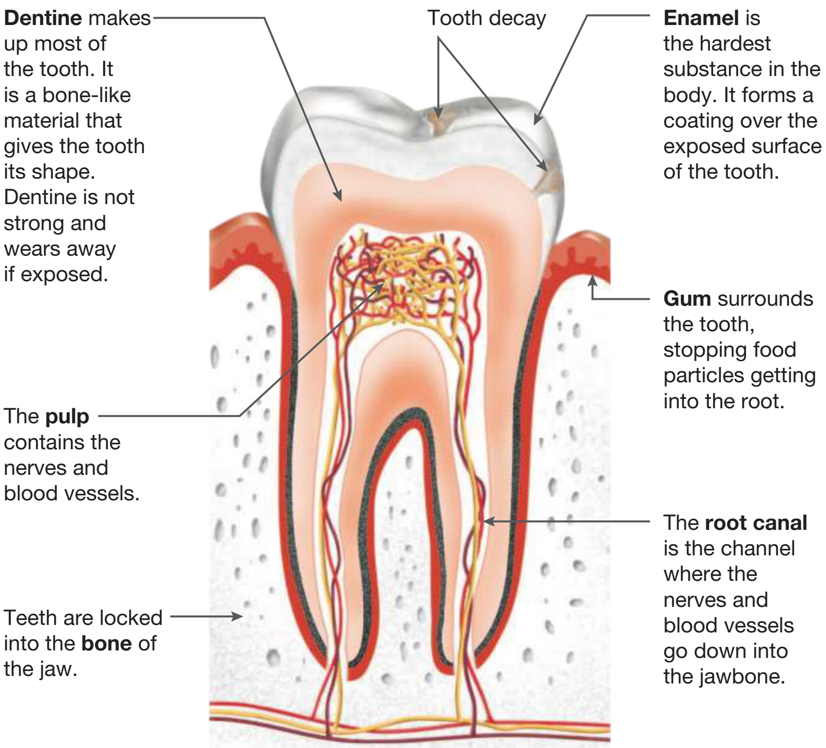
Do you drink tap or bottled water?

Our water supply and toothpaste often contain fluoride, which helps prevent tooth decay. Fluoride protects the enamel and helps repair or rebuild the enamel in your teeth. If you have replaced drinking tap water with bottled water, read the label and find out if it has fluoride in it. In which other ways is bottled water different from tap water? Can drinking bottled water instead of tap water affect the health of your teeth?

Clean your teeth for good health

Poor teeth hygiene has been linked to poor general health and a number of systemic conditions, including heart disease, endocarditis, pregnancy and birth complications, and pneumonia. This is because the mouth is an entry point for bacteria.

FIGURE 3.31 The structure of a tooth, showing where tooth decay occurs



3.5.3 A future in teeth?

Dentistry is only one example of many different 'tooth pathway' careers that you may be aware of. Examples of other dental professionals include oral and maxillofacial surgeons, dental–maxillofacial radiologists, endodontists, oral physicians, oral pathologists, orthodontists, paediatric dentists, periodontists, prosthodontists, public health dentists and special needs dentists.

FIGURE 3.32 Oral surgery is one of the many tooth-related careers you can choose from.

FIGURE 3.33 Missing a tooth? A synthetic replacement for a tooth root is used in a tooth implant.

3.5.4 Do you have the stomach for it?

In 1822, Dr William Beaumont began studying the stomach after a patient of his survived a close-range gunshot wound. The wound healed but left an opening that exposed the inside of his patient's stomach. Using this opportunity, Dr Beaumont conducted groundbreaking experiments, such as suspending food on a silk thread, to uncover how the stomach functions. Almost 200 years later, Australian scientists Dr Barry J. Marshall and Dr Robin Warren (figure 3.35) made the discovery that linked *Helicobacter pylori* bacteria to gastroduodenal disease and, as a result, radically improved how peptic ulcer disease is treated.

FIGURE 3.34 Dr William Beaumont made some breakthrough discoveries on how our stomachs work.

FIGURE 3.35 Australian scientists Dr Barry J. Marshall and Dr Robin Warren received the 2005 Nobel Prize in Medicine for their discovery that linked *Helicobacter pylori* bacteria to gastroduodenal disease.

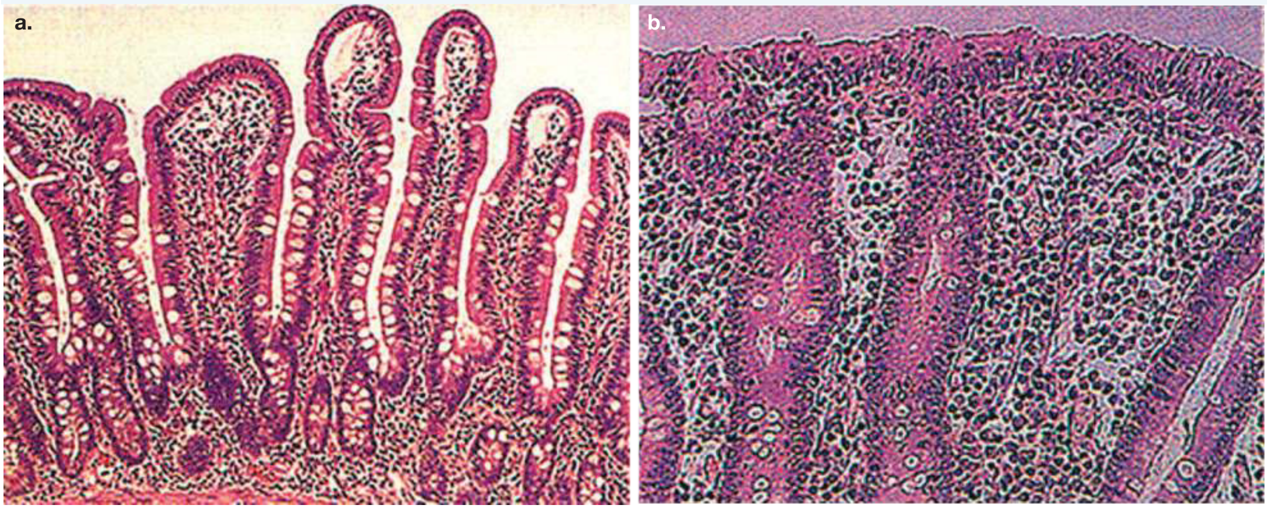
3.5.5 Villi alert!

The last section of your small intestine is lined with finger-like projections called villi. Their shape increases the surface area available for nutrients to diffuse through them into tiny blood vessels called capillaries. Once in the bloodstream, the nutrients are transported to other parts of your body.

Coeliac disease

Coeliac disease is an auto-immune disease — that is, one in which your body produces antibodies to attack your own tissues. In this case, the immune system reacts abnormally to gluten. As a result, the villi of the small intestine become inflamed and flattened (figure 3.36b). This reduces the surface area available for the absorption of nutrients.

FIGURE 3.36 Biopsies of **a.** normal intestine and **b.** coeliac intestine



Coeliac Australia refers to coeliac disease as a 'hidden epidemic'. Although about 1 in 70 people in Australia have been diagnosed with the condition, many (about 80 per cent) do not know that they have it. If left undiagnosed, more severe consequences — such as a variety of nutritional deficiencies, bowel cancer and **osteoporosis** — may result.

SCIENCE AS A HUMAN ENDEAVOUR: Advancements in coeliac disease research

Coeliac disease is an autoimmune condition triggered by the ingestion of gluten, a protein found in wheat, rye, barley and oats. For people with this condition, eating gluten leads to an immune reaction that damages the small intestine, causing symptoms such as abdominal pain, fatigue and nutrient deficiencies. The only current management is a strict gluten-free diet.

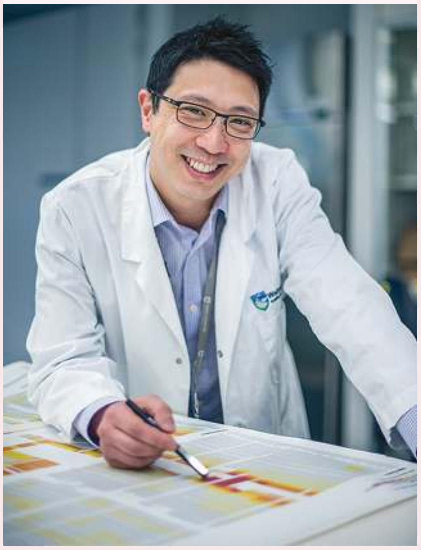
Challenges in vaccine development

In 2009, Australian researchers launched the world's first trials for a vaccine aimed at helping those with coeliac disease tolerate gluten. Despite early promise, the phase 2 trials of Nexvax2® were discontinued in 2019. While this was a setback, researchers remain dedicated to finding effective treatments for coeliac disease beyond dietary management.

Breakthroughs in blood testing

In 2019, researchers identified unique markers in the blood of people with coeliac disease shortly after they consumed gluten. This discovery was the result of an international collaboration, including Australian researcher Associate Professor Jason Tye-Din of the Walter and Eliza Hall Institute of Medical Research. The finding opened the door for simpler, faster diagnostic blood tests that may one day replace invasive procedures such as intestinal biopsies.

FIGURE 3.37 Associate Professor Jason Tye-Din, Head of coeliac research at Australia's Walter and Eliza Hall Institute of Medical Research and a gastroenterologist at The Royal Melbourne Hospital



The role of collaboration

This research highlights the importance of multidisciplinary collaboration. Advances in coeliac disease treatment and diagnosis rely on expertise from fields such as immunology, gastroenterology and molecular biology, as well as cooperation between countries.

Recent advancements in coeliac disease

Researchers have been testing a new drug called ZED1227. This drug works by blocking an enzyme in the body called transglutaminase 2 (TG2). TG2 plays a role in how the body reacts to gluten, causing the immune system to attack the small intestine. Early studies show that ZED1227 can help protect the intestine from damage even if a small amount of gluten is eaten. This could give people with coeliac disease more freedom in their diet in the future.

Using MRI to study coeliac disease

Scientists are also using advanced imaging tools, such as magnetic resonance imaging (MRI), to better understand how coeliac disease affects the intestines. MRI allows doctors to look inside the body without needing surgery. This can help them see how well a gluten-free diet or new treatments are working and track how the intestines heal over time.

1. Why do you think it is important for scientists from different countries and disciplines to work together on diseases such as coeliac disease? How might different perspectives contribute to breakthroughs?
2. How does the development of ZED1227 show that science can create better solutions when new knowledge becomes available?

Scientific knowledge, including models and theories, can change because of new evidence (VC2S8H01)

INVESTIGATION 3.4

Observing villi

Aim

To investigate the internal structure of the lining of the small intestine

Materials

- prepared slides of the walls of the small intestine
- monocular light microscope

Method

Use a light microscope to observe the prepared slide of the walls of the small intestine.

Results

Draw a diagram of your observations. Record the magnification used, label a villus and use descriptive labels to record your detailed observations.

Discussion

1. Describe the function of a villus. (Read through the information previously given in this lesson if you are unsure.)
2. With reference to your observations, suggest how the shape of a villus suits its function.

Conclusion

Summarise the findings for this investigation.

3.5 Activities

learnon

3.5 Quick quiz on | 3.5 Exercise

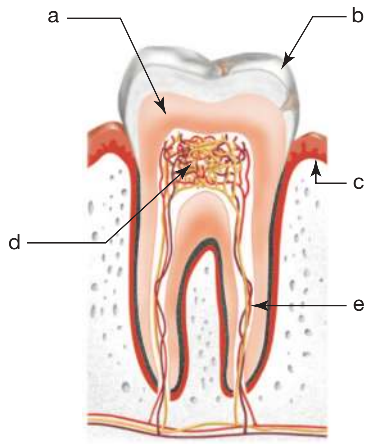
LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 4	5, 7, 8	6, 9, 10

Remember and understand

1. a. **State** whether the following statements are true or false.

Statement	True or false?
i. Acid produced from sugar in food may 'eat' a hole in your tooth enamel and dentine.	
ii. Plaque refers to a thin film of food, saliva and bacteria that may cover your teeth.	
iii. Rotting plaque can cause your gums to swell and bleed.	
iv. Fluoride may be added to the water supply or to toothpaste to increase tooth decay.	
v. It is in the last section of your large intestine where most of the nutrients are absorbed into your bloodstream.	
vi. The shape of the villi in the small intestine increases the surface area available for absorption of nutrients into capillaries.	
vii. People with coeliac disease can eat foods containing gluten.	

   b. Rewrite any false responses.
2. Label the structures (a–e) in the diagram of the tooth using the following terms: enamel, dentine, gum, pulp, root canal.



3. Match the tooth part to its description in the table shown.

Tooth part	Description
a. Dentine	A. The name of the channel where the nerves and blood vessels go down into the jawbone
b. Enamel	B. The bone-like material that gives the tooth its shape and makes up most of the tooth but, if exposed, wears away
c. Pulp	C. This forms a coating over the exposed surface of the tooth and is the hardest substance in your body.
d. Root canal	D. This part of the tooth contains most of the nerves and blood vessels.

4. **Describe** the discovery that led to two Australian scientists winning the 2005 Nobel Prize in Medicine.

Apply and analyse

5. **Outline** the relationship between diet, coeliac disease and the digestive system.
6. **State** approximately how many people in Australia are affected by coeliac disease. Consider the impact of coeliac disease on the Australian population. **Discuss** factors such as how the condition affects the health of individuals.
7. Imagine that you have invited two friends over for a sleepover. One of them has coeliac disease and the other is lactose intolerant.
   a. **List** the sorts of foods you could offer your friends.
   b. Design a breakfast and dinner menu that includes foods that each of your friends would be able to eat.
8. Design a classroom presentation where a simulated digestion process is demonstrated using models or materials. **Identify** how the process mimics digestion in the human body, and **explain** which parts represent specific digestive organs.

Evaluate and create

9. Design your own digestive aid that addresses a specific challenge, such as lactose intolerance or gluten sensitivity. Develop a labelled diagram or description to **explain** how your aid works and why it could be more effective or beneficial than existing options.
10. SI Design an investigation to test the following hypotheses:
    - Drinking fluoridated water reduces tooth decay.
    - Mouthwash prevents the growth of bacteria that cause tooth decay.
    - Drinking bottled water rather than tap water increases tooth decay.

Answers and sample responses are available in your digital formats.

LESSON 3.6 Circulatory system — blood highways

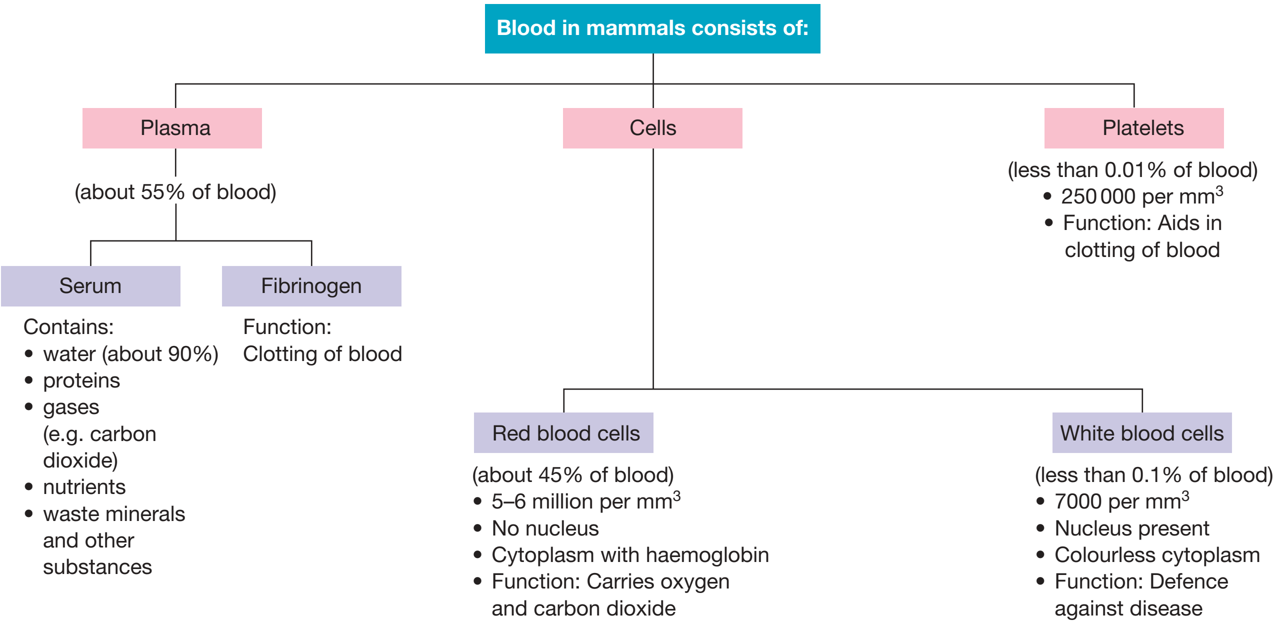
LEARNING INTENTION

In this lesson you will describe the structure and function of the circulatory system.

3.6.1 What is in blood?

An average-sized human has about five litres of blood; that's about a bucketful. Blood is made up of red blood cells (**erythrocytes**), white blood cells (**leucocytes**), blood platelets and the straw-coloured fluid they all float in, called **plasma** (figure 3.38).

FIGURE 3.38 You have all of this in your blood.

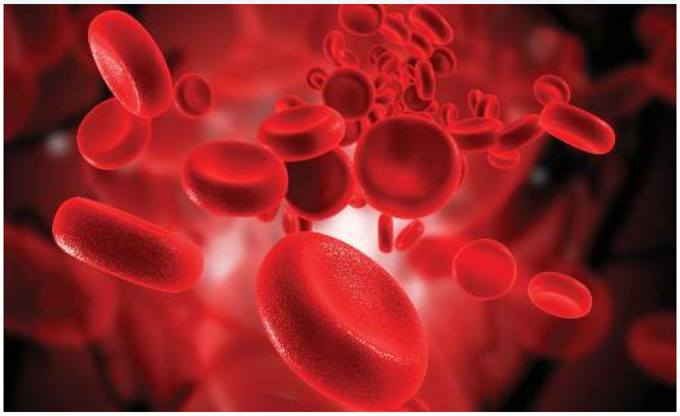


Ready to carry!

Each drop of blood contains about 300 million **red blood cells** with the important job of carrying oxygen around your body. Red blood cells are red because they contain an iron-containing pigment called **haemoglobin**. Oxygen reacts with haemoglobin in red blood cells to form oxyhaemoglobin, which makes the blood an even brighter red. This change in colour intensity can indicate the amount of oxygen being transported in blood at a particular time.

The shape and size of red blood cells make them well suited to their function. Their small size allows them to fit inside tiny capillaries. When mature, red blood cells lack a nucleus, increasing space available to carry haemoglobin and hence oxygen. Their biconcave shape means that they have a large surface area for their size, which also assists in their important oxygen-transporting role.

FIGURE 3.39 These red blood cells (erythrocytes) travel around the body up to 300 000 times (or for about 120 days). After this, they wear out and die. Fortunately, each second, you are manufacturing about 1.7 million replacement red blood cells in your bone marrow.



EXTENSION: The effect of altitude on oxygen levels in blood

The amount of oxygen carried by haemoglobin varies with altitude. At sea level, about 100 per cent of haemoglobin combines with oxygen. At an altitude of 13 000 metres above sea level, however, only about 50–60 per cent of haemoglobin combines with oxygen.

Fit to fight!

White blood cells contain a nucleus, and are larger and fewer in number than red blood cells. They are often referred to as the 'soldiers' in the blood as they are involved in fighting disease. Some white blood cells produce chemicals called antibodies; others engulf and 'eat' bacteria and other foreign matter. When you are ill or fighting an infection, the number of white blood cells in your blood increases for this reason.

Clot and cover …

If you cut yourself, you bleed. This is because a blood vessel has been cut. **Platelets** in the blood help it to clot and plug the damaged blood vessel. This seal prevents germs getting in.

EXTENSION: Blood pigments

Insect blood looks a little like raw egg white, because it contains no pigment. The blood of crabs and crayfish, however, contains the pigment haemocyanin. This pigment has copper in it and is blue when combined with oxygen. This differs from haemoglobin in humans, which is red when combined with oxygen.

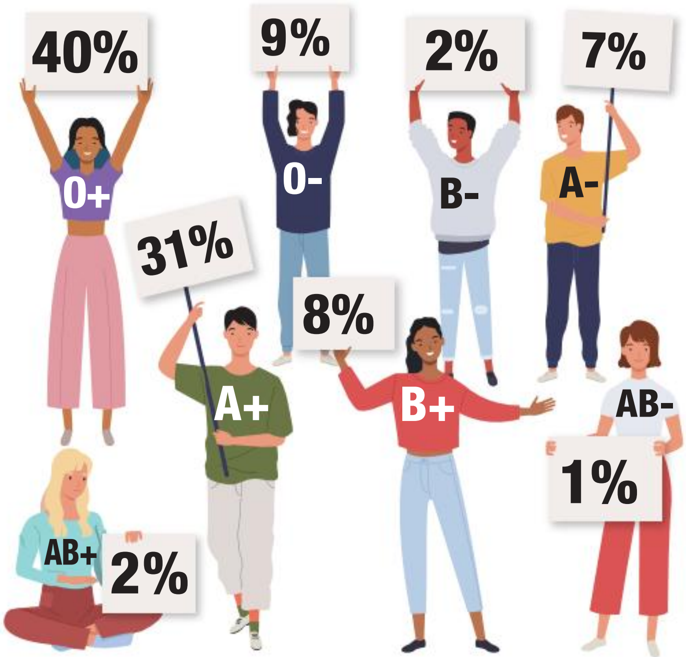
3.6.2 Mix and match?

How much do you know about the red stuff that flows throughout your body? Did you know that your blood might not mix too well with that of your friends? Blood can be grouped into eight types using the ABO system and the Rhesus (Rh) system. Your blood type is inherited from your parents.

The blood-type classification systems are based on whether particular chemicals are present or absent on your red blood cells. If you are Rh-negative, you do not have the Rhesus factor on your red blood cells; if you do, you are Rh-positive.

The ABO system divides blood into groups A, B, AB and O. If you need a blood transfusion, it is very important to know your blood type and that of the donor because some blood types cannot be mixed. If the wrong types are mixed, the blood cells may clump together and cause fatal blockages in blood vessels.

FIGURE 3.40 How common is your blood?

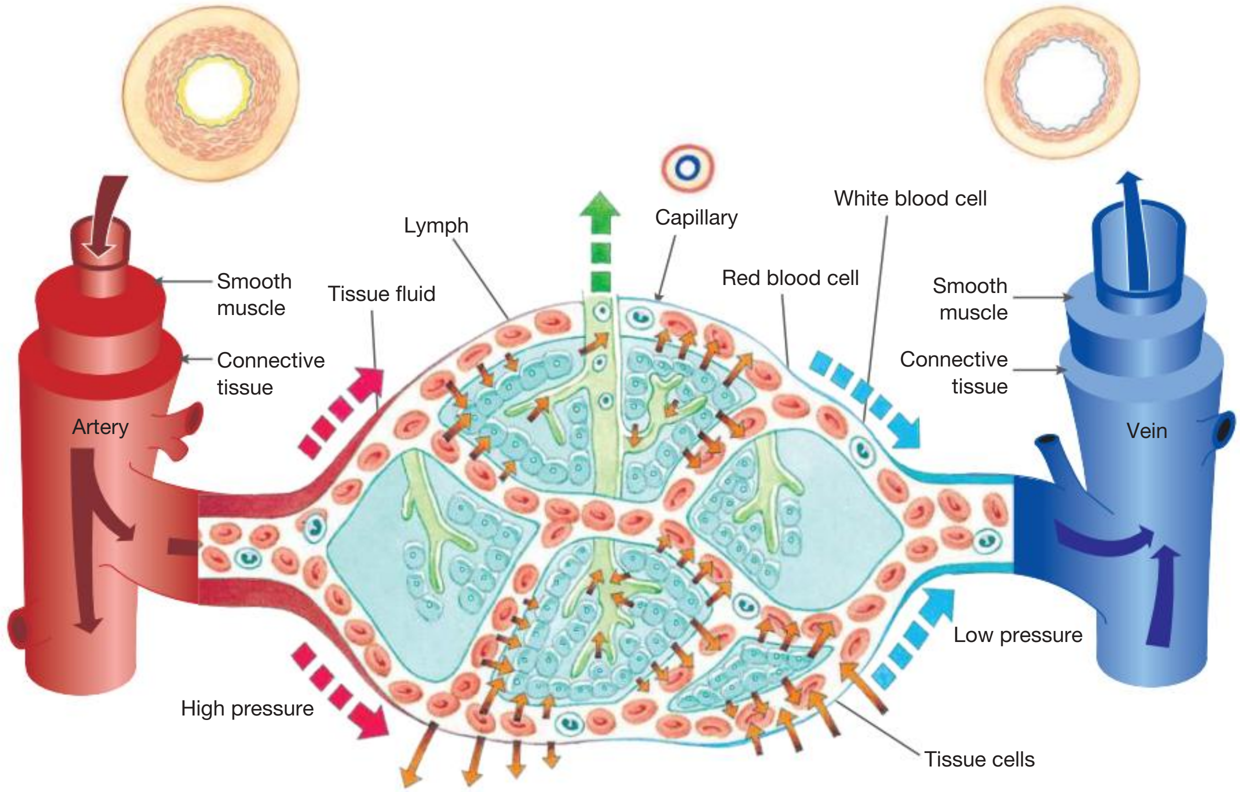


3.6.3 Connected pathways

Your circulatory system is responsible for transporting oxygen and nutrients to your body's cells, and wastes such as carbon dioxide away from them. This involves interactions between blood cells, blood vessels and your heart.

Blood vessels called arteries transport blood from your heart, whereas others, called veins, transport blood back to the heart, as seen in figure 3.41. Materials are exchanged between blood and cells through tiny blood vessels called capillaries that are located between arteries and veins.

FIGURE 3.41 Your circulatory system consists of your heart, blood vessels and blood. Arteries, capillaries and veins are the major types of blood vessels through which your blood travels.



Arteries, veins and capillaries

Arteries have thick, elastic, muscular walls and carry blood under high pressure away from your heart. Veins have thinner walls and possess valves that prevent the blood from flowing backwards as they take blood to your heart.

FIGURE 3.42 The circulatory system

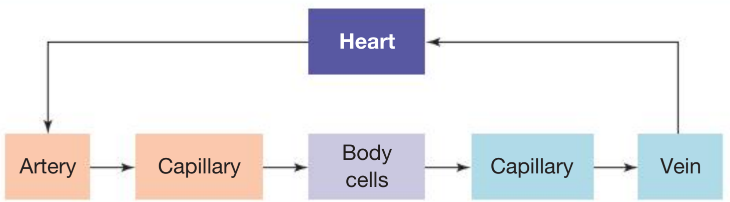
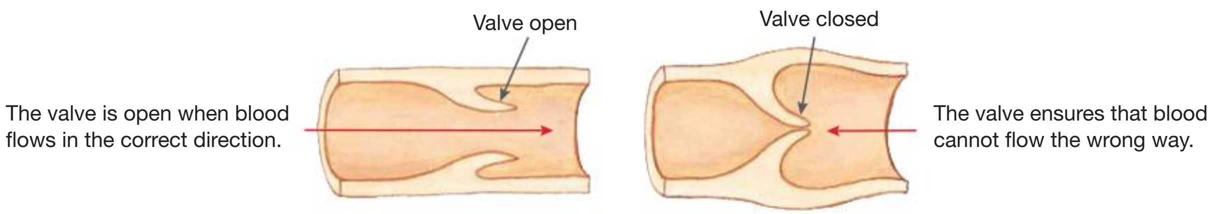


FIGURE 3.43 Veins have valves to ensure that blood flows in only one direction.

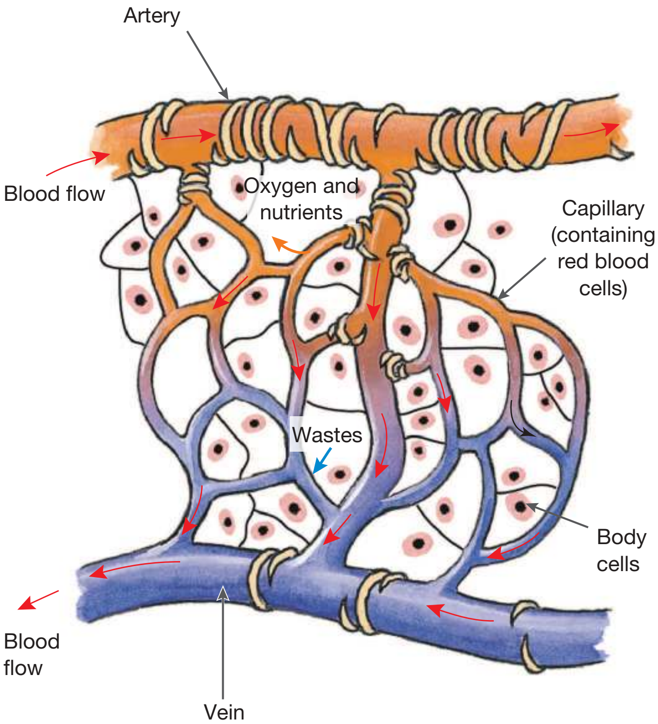


Capillaries are the most numerous and smallest blood vessels. Your body contains about 100 000 km of capillaries, which penetrate almost every tissue, so no cell is very far away from one. Capillaries are very important because they transport substances such as oxygen and nutrients to cells and remove wastes such as carbon dioxide.

If you bump yourself but have not cut your skin, a bruise may form. Bruises are caused by burst blood capillaries under your skin. The bruise changes from black to purple to yellow as the blood clears away.

FIGURE 3.44 As the blood clears away from a bruise the colour changes.

FIGURE 3.45 In the capillaries, oxygen diffuses out of the blood and waste produced by cells diffuses into the bloodstream.



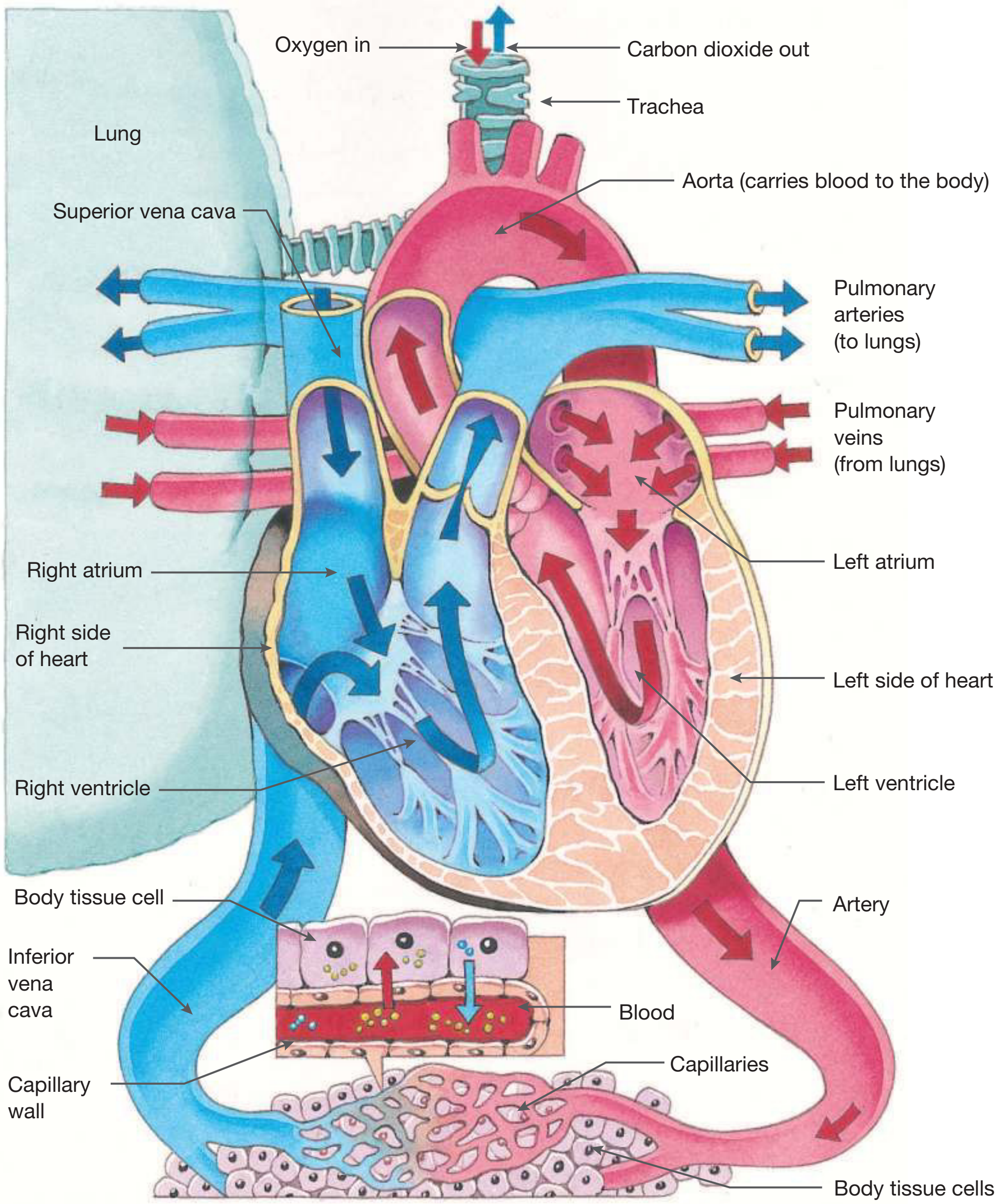
3.6.4 Have a heart

Often linked with emotions, love and courage, the heart has a special meaning for most of us. In a clinical sense, however, it is merely a pump about the size of your clenched fist. It is located between the lungs, slightly towards the left-hand side, which explains why the left lung is slightly smaller.

The heart is responsible for the movement of blood throughout the body, circulating oxygen, carbon dioxide and other molecules in a continuous cycle as seen in figure 3.47.

FIGURE 3.46 A 3D image of the location of the heart between the lungs

FIGURE 3.47 The movement of blood through the heart



Two pumps in one

To be more precise, the human heart is actually *two* pumps. One side contains **oxygenated blood** and the other **deoxygenated blood**. Veins bring 'used' deoxygenated blood from cells in your body back to your heart. Stripped of its oxygen, the deoxygenated blood is a dull, dark red colour. The blue colour of veins is due to the way light interacts with the skin and the walls of the veins, not the blood inside them. All of these veins join up into a larger vein called the **vena cava**.

Entering the top-right chamber of your heart, blood is pumped into the bottom-right chamber. It is then pumped out to your lungs, where it picks up oxygen and becomes oxygenated and a much brighter red in colour. It also loses some of its carbon dioxide. The oxygenated blood then returns via a vein from your lungs to the left-hand side of your heart to be pumped out through arteries to your body tissues, where it delivers oxygen and nutrients. The deoxygenated blood then returns to the right-hand side of the heart for the cycle to be repeated. This can be seen in figure 3.48 which is a simplified flow chart of how blood is pumped around the body.

Four chambers

The human heart has four chambers.

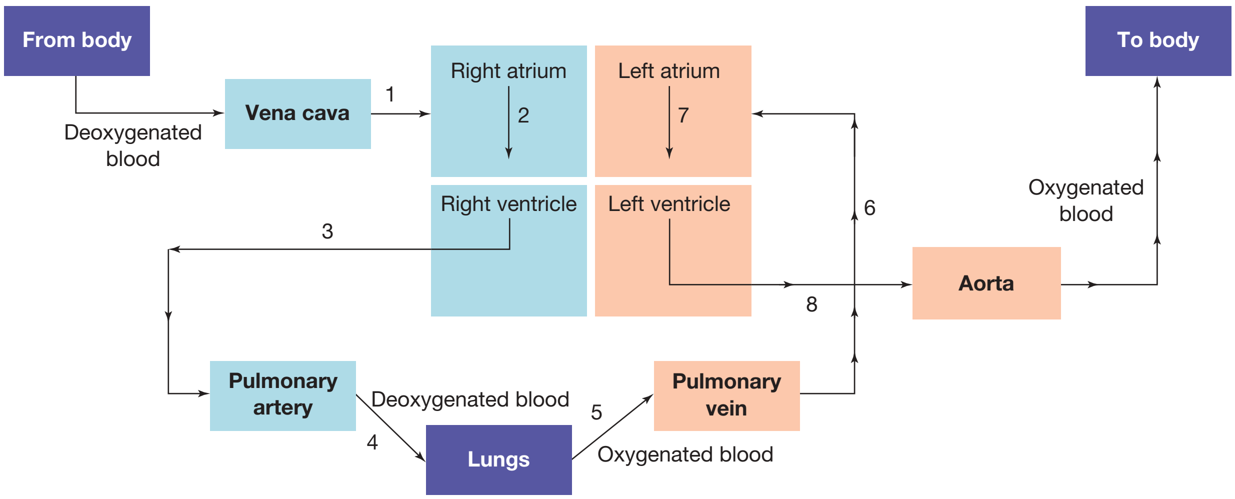
The upper two chambers are called the:
- **left atrium**
- **right atrium** (plural = atria).

The lower two chambers are called the:
- **left ventricle**
- **right ventricle**.

The two sides of the heart are different. The walls of the left side are thicker and more muscular because they need to have the power to force the blood from the heart to the rest of the body.

Flap-like structures attached to the heart walls, called **valves**, prevent the blood from flowing backwards and keep it going in one direction. If you listen to your heart beating, you will hear a **'lub dub'** sound. The 'lub' sound is due to the valves between the ventricles and atria shutting. The 'dub' sound is due to the closing of the valves that separate the heart from the big blood vessels that lead to the lungs and the rest of the body.

FIGURE 3.48 The heart is actually two pumps. One side pumps oxygenated blood and the other deoxygenated blood.



3.6.5 Blood pressure

The heart's pumping action and the narrow size of the blood vessels result in a build-up of considerable pressure in the arteries. The force with which blood flows through the arteries is called **blood pressure**. It is affected by different activities and moods. It also goes up and down as the heart beats, being highest when the heart contracts (**systolic pressure**) and lowest when the heart relaxes (**diastolic pressure**). A person's blood pressure is expressed as a fraction. This fraction is the systolic pressure over the diastolic pressure, such as 120/70.

SCIENCE INQUIRY: Exploring blood pressure

Blood pressure is the force of blood pushing against the walls of arteries as the heart pumps. It fluctuates depending on the contraction and relaxation of the heart muscles. Blood pressure readings are expressed as a fraction, with systolic pressure (higher number) representing the pressure during heart contraction and diastolic pressure (lower number) representing the pressure during relaxation. Activities, emotions and health conditions can all influence blood pressure.

Understanding blood pressure helps us learn about the cardiovascular system and how our bodies respond to different situations, such as exercise or stress.

For example:
- Systolic pressure rises when the heart pumps blood forcefully.
- Diastolic pressure reflects the resting phase of the heart.

This knowledge is crucial for understanding health and detecting conditions such ashypertension.

1. How do you think activities such as running or relaxing affect systolic and diastolic blood pressure? What patterns would you expect to observe and why?
2. If someone experiences prolonged stress or anxiety, how might their blood pressure readings change over time? What predictions can you make about the long-term effects on their cardiovascular system?

Investigable questions, reasoned predictions and hypotheses can be developed in guiding investigations to identify patterns, test relationships and analyse and evaluate scientific models (VC2S8I01)

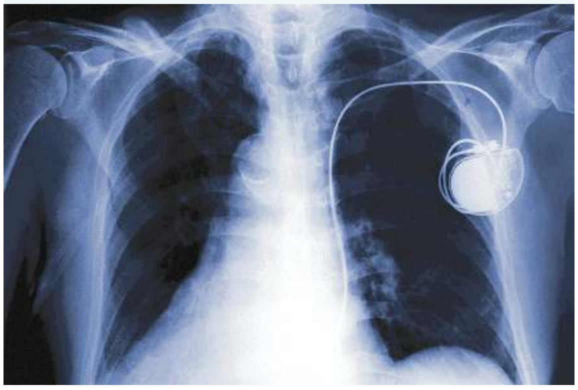
3.6.6 Keeping the pace

During each minute that you are sitting and reading this, about 5–7 litres of blood completes the entire circuit around your body and lungs. In a single day, your heart may beat about 100 000 times and pump about 7000 litres of blood around your body.

A normal human heart beats about 60–100 times a minute, with this rate increasing during exercise or stress. With each **heartbeat**, a wave of pressure travels along the main arteries. If you put your finger on your skin just above the artery in your wrist, you can feel this **pulse** wave as a slight throb. Your pulse rate after exercise can be used as a guide to your physical fitness. The fitter you are, the quicker your heart rate will return to its resting rate after vigorous exercise.

The regular rhythmic beating of the heart is maintained by electrical impulses from the heart's **pacemaker**, which is located in the wall of the right atrium. Some people with irregular heartbeats are fitted with artificial, electronic pacemakers to regulate the heart's actions and correct abnormal patterns.

FIGURE 3.49 A person fitted with an artificial pacemaker



Try clenching your fist every second for five minutes. Getting a little tired? The heart is made up of special muscle called **cardiac muscle**, which never tires. Imagine having a 'cramp' or 'stitch' in your heart after running to catch the bus! Owing to its unique electrical properties, heart muscle will continue to beat even if it is removed from the body. Scientists have shown that even tiny pieces of this muscle cut from the heart will continue to beat when they are placed in a test tube of warm salty solution.

INVESTIGATION 3.5

Viewing blood cells

Aim

To observe blood cells under a light microscope

Materials

- prepared slide of blood smear
- microscope

Method

1. Place the prepared slide onto the microscope stage.
2. Use low power to focus, then carefully adjust to high power.
3. Find examples of red blood cells and white blood cells on the slide.

Results

1. Draw diagrams of representative red blood cells and white blood cells. On your diagram, include descriptive labels and the magnification used.
2. Estimate (a) how many red blood cells could fit inside a white blood cell and (b) how many of each cell type could fit across the field of view.

Discussion

1. Summarise the similarities and differences between the structures of red blood cells and white blood cells.
2. Suggest reasons for the differences.
3. Find out more about the structural differences between red blood cells and white blood cells.
4. Describe how the structure of each type of blood cell suits it to its function.

Conclusion

Summarise the findings for this investigation.

INVESTIGATION 3.6

Heart dissection

Aim

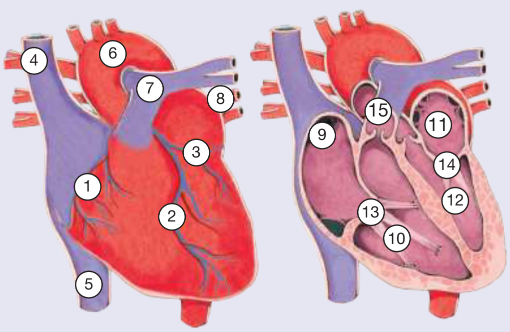
To observe the structure of a mammalian heart

Materials

- sheep's heart, preferably with the blood vessels still attached
- dissecting instruments
- dissecting board
- newspaper or paper to cover dissection board

Method

1. Place newspaper on the dissection board, then place the heart on top of the paper.
2. Use the diagram shown to identify the parts of the heart.



1. Right coronary artery
2. Left anterior descending coronary artery
3. Circumflex coronary artery
4. Superior vena cava
5. Inferior vena cava
6. Aorta
7. Pulmonary artery
8. Pulmonary vein
9. Right atrium
10. Right ventricle
11. Left atrium
12. Left ventricle
13. Tricuspid valve
14. Mitral valve
15. Pulmonary valve

3. Try to locate where blood enters and leaves the heart:
   a. to and from the lungs
   b. to and from the rest of the body.
4. Cut the heart in two so that both halves show the two sides of the heart (similar to the illustration in figure 3.47).

Results

1. Sketch and label the heart and use arrows to show the direction of blood flow.
2. In a diagram, record your observations of the thickness of the walls on the left side of the heart compared with the right side.
3. Suggest reasons for the differences observed.
4. Try to locate the valves in the heart.

Discussion

1. Describe the valves and suggest their function.
2. Write a summary paragraph about the structure and function of the heart.

Conclusion

Summarise the findings for this investigation.

3.6 Activities

learnon

3.6 Quick quiz on	3.6 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 3, 4, 9, 10, 11, 19	2, 5, 6, 12, 13, 15, 20, 22	7, 8, 14, 16, 17, 18, 21, 23

Remember and understand

1. a. **State** whether the following statements are true or false.

Statement	True or false?
i. The human heart is made up of three chambers.	
ii. Valves in the heart prevent blood from flowing backwards and keep it going in one direction.	
iii. The walls on the left side of the human heart are thicker and more muscular than those on the right.	
iv. The 'dub' sound is due to the closing of the valves between the ventricles and atria shutting.	
v. Arteries take blood to and from the heart.	
vi. The force with which blood flows through the arteries is called blood pressure.	
vii. Systolic pressure results when the heart relaxes.	
viii. You are considered to be Rh-negative if you have the Rh antigen in your red blood cells.	
ix. The right side of the human heart pumps deoxygenated blood to the lungs.	

   b. Rewrite any false responses.

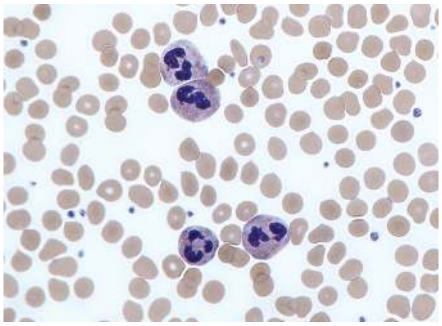
2. What am I? **State** another name for each of the following.
   a. Red blood cell
   b. Leucocyte
   c. The straw-coloured fluid in which blood cells float
   d. A cell fragment involved in clotting of the blood
   e. The iron-containing pigment that gives red blood cells their colour
3. Match the circulatory system term with its description in the table shown.

Term	Description
a. Artery	A. The bottom two chambers of the heart
b. Atria	B. Cell involved in transporting oxygen around the body
c. Capillary	C. Blood vessel that takes blood to the heart
d. Heart	D. Cell involved in protection against infection
e. Red blood cell	E. Blood vessel that takes blood away from the heart
f. Vein	F. The top two chambers of the heart
g. Ventricles	G. Organ that pumps blood around the body
h. White blood cell	H. Blood vessel that exchanges substances with cells

4. **List** the following in the order that a red blood cell would travel after leaving the aorta: pulmonary artery, left ventricle, right atrium, intestine, lung, pulmonary vein, left atrium, liver, right ventricle.
5. **Outline** what blood is and what blood does.
6. **Name** and **describe** the types of blood vessels in which blood travels around your body.
7. **Describe** the relationship between arteries, capillaries and veins.

Apply and analyse

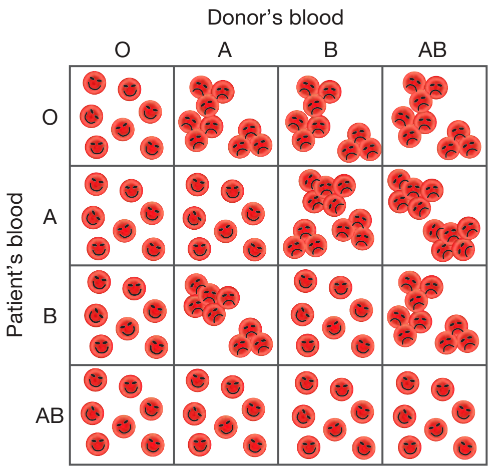
8. a. **Describe** what is unusual about cardiac muscle.
   b. **Describe** what blood pressure is caused by.
   c. **Explain** why there are valves in the heart.
9. a. **State** how many times a normal human heart beats each minute.
   b. **Suggest** what may cause the heart rate to increase.
   c. **Explain** how the rhythmic beating of the heart is maintained.
10. Carefully **examine** figure 3.40. Which blood type is the most common? Which is the least common?
11. SI **Construct** an appropriate graph to show the different proportions of blood components.
12. The higher the altitude, the less oxygen there is in the air. **Propose** a reason people living at high altitudes usually have more red blood cells than people living at low altitudes.
13. Think of other ways that information about the components of blood could be organised visually. Organise the material in one of these ways.
14. a. Copy figure 3.48 onto a sheet of paper.
    b. Use red and blue coloured pencils to show the path taken for a red blood cell to travel from the vena cava to the aorta. Use a red coloured pencil to indicate oxygenated blood and a blue coloured pencil to show deoxygenated blood.
    c. In your diagram, indicate which two blood vessels transport:
       i. deoxygenated blood
       ii. oxygenated blood.
    d. Use an 'X' to indicate which blood vessel you would expect to have the highest blood pressure.
15. Observe the image of human blood cells shown.
    a. **Identify** which are white blood cells and which are red blood cells.
    b. **Describe** how you distinguished between the two types of blood cells.
    c. Which are in the greatest abundance? **Suggest** a reason for this.



16. **Compare** the difference between:
    a. the blood in the two sides of the heart
    b. the structure of the two sides of the heart
    c. systolic and diastolic pressure.

Evaluate and create

17. **Compare** red blood cells, white blood cells and blood platelets.
18. Blood transfusions involve an injection of a volume of blood, previously taken from a healthy person, into a patient. This has to be done carefully, as if the wrong type of blood is injected, the blood will clump and the patient could die. Carefully **examine** the figure, which shows which blood group combinations may be compatible for a blood transfusion.
    a. Which blood group(s), A, B, AB or O, can be accepted by:
        i. all blood groups
        ii. blood group AB
        iii. blood group A?
    b. Which blood group, A, B, AB or O, can receive transfusions from all blood types?



19. a. Complete the table by listing the structural features and functions of the following parts of the circulatory system.

Part of circulatory system	Structural features	Function
Arteries		
Veins		
Capillaries		
Red blood cells		
White blood cells		

    b. Convert the information in the table into a Venn diagram, target map or another visual thinking tool.
20. a. Some people have religious grounds for disagreeing with the use of blood transfusions. Imagine a four-year-old child with a life-threatening condition. Her parents will not allow her to have the blood transfusion that she needs. What should the doctors do? **Justify** your decision.
    b. Would your response be different if the child was 18 years old and wanted the blood transfusion, but her parents would not allow it? **Justify** your decision.
21. A day after donating blood, a person finds that they have an infectious disease that can be transmitted by blood. **Suggest** what they should do.
22. **Construct** a PMI chart for a law that makes it compulsory for everyone over 16 to donate blood at least once a year.
23. Imagine that you have a friend who is anaemic. They are constantly tired and very pale.
    a. **Assess** what you could do to help your friend improve their health.
    b. **Summarise** your ideas in a cluster map or mind map.
    c. Decide on a strategy for helping your anaemic friend.

Answers and sample responses are available in your digital formats.

LESSON 3.7 Transport technology

LEARNING INTENTION

In this lesson you will provide examples of how, due to discoveries made using new and improved technologies, our understanding of the circulatory system has changed over time.

3.7.1 Scientific theories can change over time

Our understanding of the circulatory system has been built by scientists and physicians throughout human history. With new observations and evidence, some theories have been discarded and others developed or modified. New technologies have enabled new observations to be made, which have resulted in new ways of thinking about the structure and functioning of the human body.

Claudius Galen (*c*.129–*c*.199 AD)

For over a thousand years, the key training books used for doctors were based on the ideas of the Greek physician Claudius Galen. Galen's ideas were based on his observations of dissections of animals (other than humans). Galen described the human heart as being made up of two chambers and also being the source of the body's heat. He believed that blood was made by the liver and travelled to the right chamber of the heart, and that the left chamber made 'vital spirits' which were then transported by arteries to body organs. He was the first to use the pulse as a diagnostic aid.

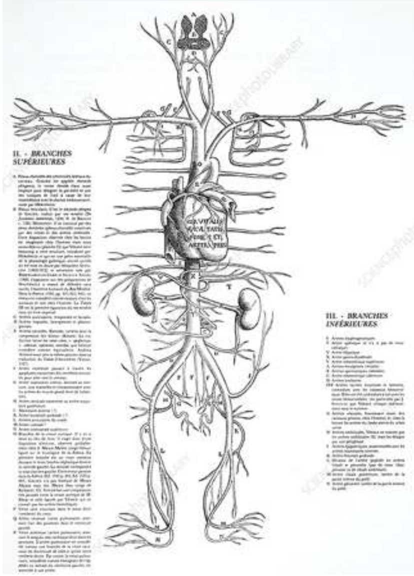
FIGURE 3.50 Claudius Galen (*c*.129–*c*.199 AD)

Andreas Vesalius (1514–1564)

Hundreds of years later another physician, Andreas Vesalius (figure 3.51), began to transform medical knowledge — by questioning all previous theories. He believed that it was necessary to dissect bodies to find out how they worked. As the Church did not allow this, he took bones from graves and even stole a body from the gallows. His drawings showed the positions and workings of the muscles and organs in the body (figure 3.52). Vesalius's observations proved that some of Galen's theories were wrong and he discovered anatomical structures previously unknown. His findings helped establish surgery as a separate medical profession.

FIGURE 3.51 Andreas Vesalius (1514–1564), Belgian anatomist, dissecting a cadaver. Vesalius was made professor of anatomy and surgery at Padua University, Italy, in 1537.

FIGURE 3.52 Artwork by Andreas Vesalius in 1543, showing the circulatory system



William Harvey (1578–1657)

Although Vesalius had assisted in revising the structure of the human heart, there was still confusion about its function. About 100 years later, William Harvey (figure 3.53), an English physician, conducted a series of circulation experiments (figure 3.54) that showed the way valves in the veins control the flow of blood back to the heart. The publication of this work in *On the Motion of the Heart and Blood in Animals* (1628) led to another change in how we think about the heart and our circulatory system.

FIGURE 3.53 English physician, William Harvey (1578–1657)

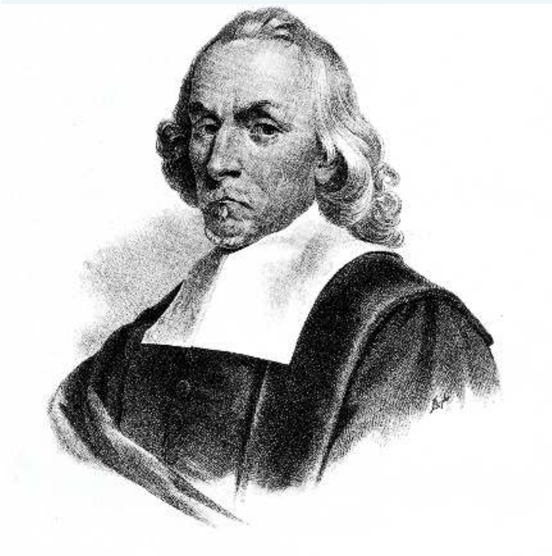
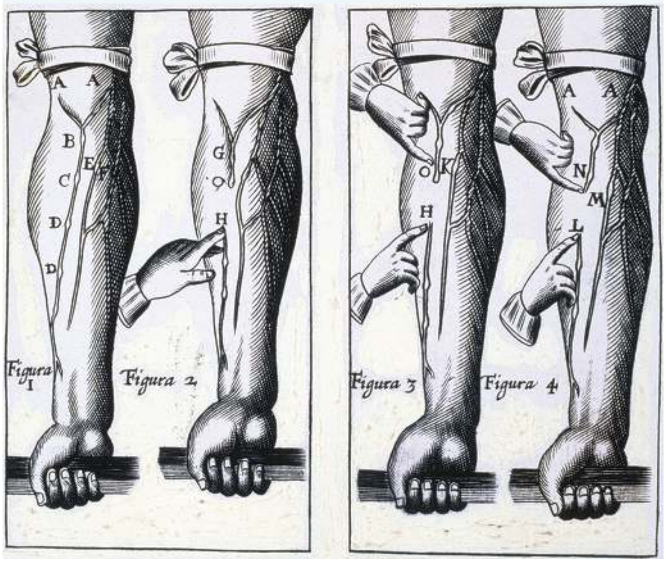


FIGURE 3.54 William Harvey's artwork of an arm with a tourniquet shows the way the valves in the veins control the flow of blood back to the heart.



3.7.2 Heart technology

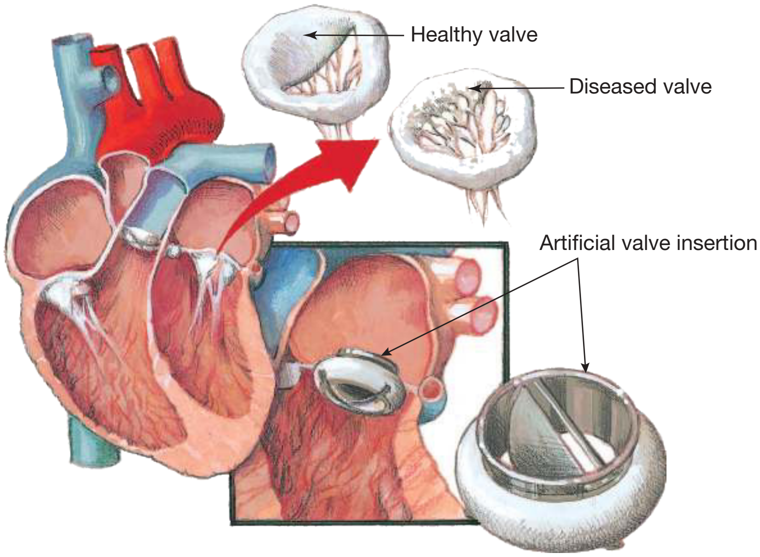
Heart and blood vessel diseases are a key cause of death for many Australians. Medical research and new technologies strive to minimise the effects of diseases and disorders of the circulatory system.

Faulty heart and vein valves

The heart, like many other pumps, depends on a series of valves to work properly. These valves open and close to receive and discharge blood to and from the chambers of the heart. They also stop the blood from flowing backwards. If any of the four heart valves becomes faulty, the function of the heart may be impaired.

Veins throughout the body may also contain valves that keep the blood flowing in one direction. Defective valves in leg veins can cause blood to drain backwards, and to pool in the veins closest to the skin surface. These veins can become swollen, twisted and painful, and are called **varicose veins**.

FIGURE 3.55 A faulty heart valve may be replaced by an artificial valve. Why are the heart valves so important to the functioning of the heart?



3.7.3 'If I only had a heart . . .'

For those with a heart that no longer works, a transplant is the best option, but this requires a compatible donor. In Australia there are more than 100 people waiting for a heart transplant at any one time, which means there are waiting times of up to two years.

Artificial hearts

The tin man from *The Wizard of Oz* would have been very happy with the development of an artificial heart (figure 3.56). This mechanical device is made of titanium and plastic. Surgeons also implant a small electronic device in the abdominal wall to monitor and control the pumping speed of the heart. An external battery is strapped around the waist and can supply about 4–5 hours of power. An internal rechargeable battery is also implanted inside the wearer's abdomen. This is so they can be disconnected from the main battery for about 30–40 minutes for activities such as showering.

FIGURE 3.56 An artificial heart can be made from metals, ceramics and polymers.

Genetically modified animal hearts

In January 2022, the first pig heart was inserted into a man in the United States. The pig embryo had been genetically modified so that it would not cause the human body to reject the heart as foreign. While the man only lived for an additional six weeks, there are hopes that this technology can be refined to overcome the present organ shortage.

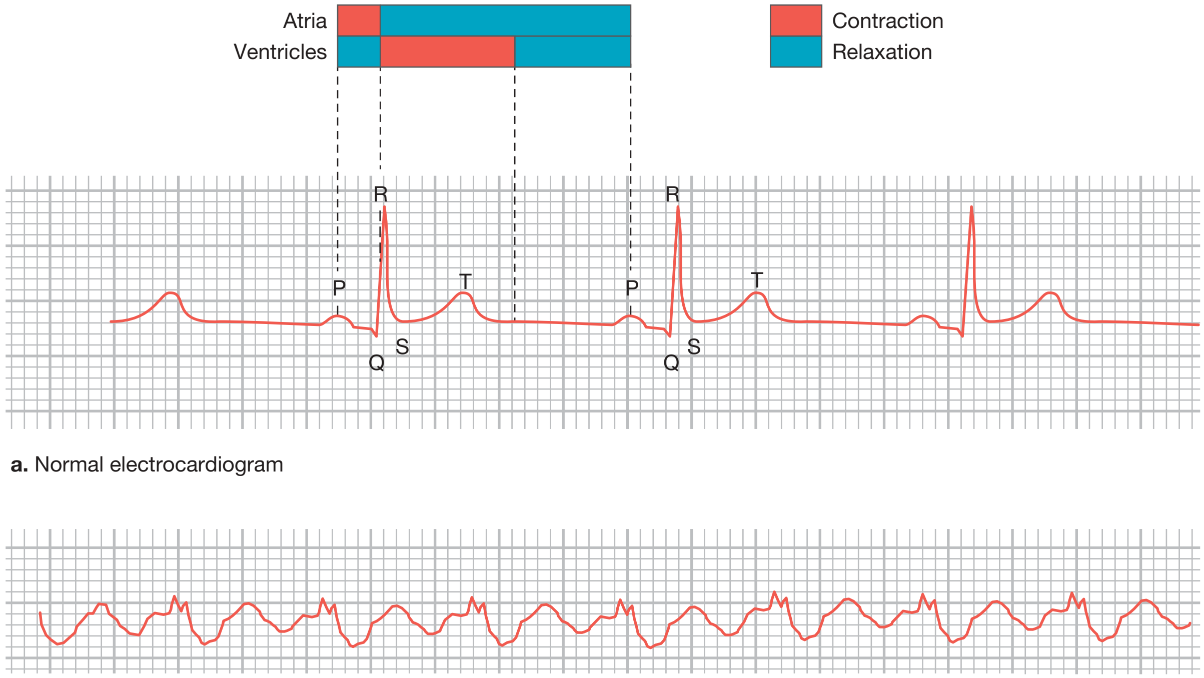
3.7.4 A heart — but no pulse?

If only the left ventricle is damaged, and the rest of the heart is in good working order, a back-up pump may be implanted alongside the heart. One model of these devices results in its wearers having a gentle whirr rather than a pulse. This is the sound of the propeller spun by a magnetic field to force a continuous stream of blood into the aorta.

Getting the beat!

An **electrocardiogram (ECG)**, as seen in figure 3.57, shows the electrical activity of a person's heart. ECG patterns are valuable in diagnosing heart disease and abnormalities.

FIGURE 3.57 Electrocardiograms



a. Normal electrocardiogram

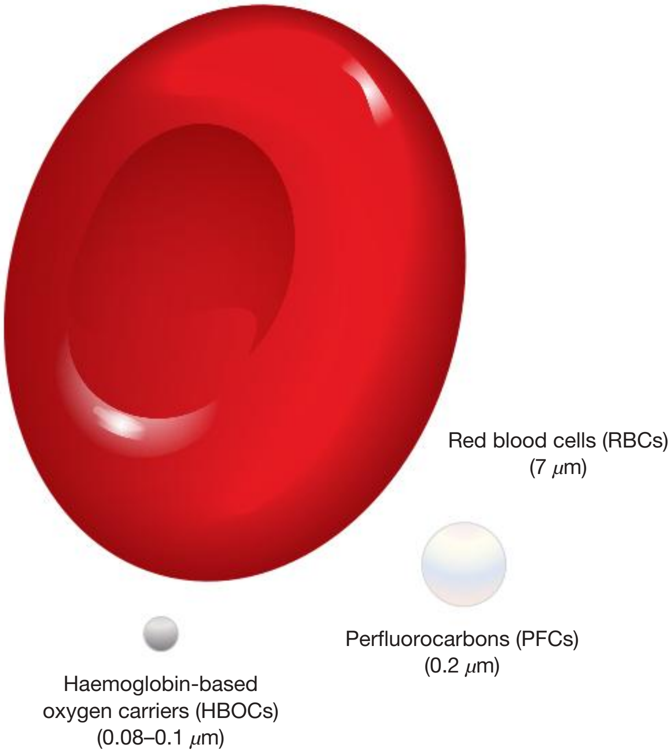
b. Abnormal electrocardiogram

3.7.5 Artificial blood

The recent wave of interest in vampire movies and books has brought with it discussion about the merits of artificial blood sources. The interest in artificial blood, however, is not new; people have thought about its use in blood transfusions for hundreds of years. William Harvey's description in 1628 of how blood circulated through the body prompted a variety of unsuccessful investigations into the use of alternative fluid substitutes. A shortage of blood supplies during war and disease epidemics has fired up the quest for an artificial blood substitute. Currently, the two most promising red blood cell substitutes are haemoglobin-based oxygen carriers (HBOCs) and perfluorocarbon-based oxygen carriers (PFCs).

PFCs are usually white, whereas HBOCs are a very dark red. Although PFCs are entirely synthetic, HBOCs are made from sterilised haemoglobin. The haemoglobin may be from human or cow blood, human placentas or bacteria that have been genetically engineered to produce haemoglobin. As the haemoglobin does not have a cell membrane to protect it, various techniques are used to make it less fragile. Some scientists are even investigating the idea of wrapping it in an artificial membrane.

FIGURE 3.58 Human red blood cells are much larger than HBOCs and PFCs.



CASE STUDY: Transplant pioneer

If your heart or lungs were not working properly and you had needed a heart or lung transplant in the 1980s, the doctor to see was Dr Victor Chang.

Dr Chang was an Australian doctor who was awarded a Companion of the Order of Australia for his contribution to medicine. Dr Chang played an important role in establishing the heart transplant unit at St Vincent's Hospital in Sydney. He set up a team of 40 health professionals who were the finest in their field, and developed new procedures and techniques that led to an improved rate of success. Of his patients, 92 per cent were still alive one year after their heart or lung transplant operation and 85 per cent were still alive five years later.

FIGURE 3.59 The late Dr Victor Chang, pioneering heart transplant surgeon

The first heart transplant operation that Dr Chang carried out at St Vincent's Hospital was in 1984 on a young girl called Fiona Coote. She became Australia's youngest heart transplant survivor. Fiona is now an adult and, although she has since needed a second heart transplant, she owes her life to Dr Chang.

Dr Chang also developed an artificial heart valve, called the St Vincent heart valve, and was working on developing an artificial heart. Unfortunately, his life was tragically cut short in 1991 when he was shot.

ACTIVITY: Organ donation

- Research campaigns used to increase the rates of organ donation.
- For each campaign, run a class poll to determine if you would donate an organ based on it. Discuss the positives and negatives of each.
- Design a campaign that could be used to increase the rates of organ donation.

Artificial blood vessels?

Will the artificial blood vessels of the future be made by bacteria? Molecular biologist Helen Fink, working in Sweden, has suggested this may be the case. The cellulose produced by *Acetobacter xylinum* bacteria is strong enough to cope with blood pressure and function within our bodies, and could be used for artificial blood vessels in heart bypass operations in the future (figure 3.60).

FIGURE 3.60 In the future, will artificial blood vessels like this one be made by bacteria?

INVESTIGATION 3.7

Check your heart

Aim

To investigate the short-term effects of exercise on heart rate and blood pressure

Materials

- stopwatch
- blood pressure monitor
- optional: data logging or digital measuring devices

Method

1. Find your pulse, either on the inside of your wrist or in your neck (see the illustrations). Make sure you use two fingers, not your thumb, to find your pulse.
2. Measure and record your heart rate in beats per minute (bpm) by counting the number of times your heart beats in 15 seconds and then multiplying this number by 4.
3. Measure and record your blood pressure using the blood pressure monitor.
4. Go for a walk in the playground or around the school oval. Measure and record your heart rate and blood pressure again.
5. Run up and down a flight of stairs. Measure and record your heart rate and blood pressure again.

Two places where your pulse should be easy to find: **a.** radial location (wrist) **b.** carotid location (neck)

Results

Record your answers in the table provided.

Test	Heart rate (bpm)	Blood pressure (mmHg)
Before exercise		
After walking		
After running up stairs		

Discussion

1. What effect does exercise have on heart rate and blood pressure?
2. Identify strengths and limitations of this investigation and suggest improvements.
3. Design and carry out an experiment to test the following hypothesis: 'There is a link between a person's resting heart rate and the number of hours the person spends exercising each week'.

Conclusion

Summarise the findings for this investigation.

3.7 Activities

learnon

3.7 Quick quiz on | 3.7 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 7, 12	4, 5, 8, 13	6, 9, 10, 11, 14, 15

Remember and understand

1. a. **State** whether the following statements are true or false.

Statement	True or false?
i. Over 1700 years ago, Andreas Vesalius described the human heart as being made up of two chambers and the source of the body's heat.	
ii. Over 350 years ago, William Harvey published his findings on blood circulation, which contributed to our present-day understanding of the heart and the circulatory system.	
iii. Over 30 years ago, Victor Chang developed an artificial heart.	
iv. An electrocardiogram (ECG) shows the electrical activity of a person's heart.	
v. Defective valves in leg arteries can cause varicose veins.	

   b. **Rewrite** any false responses.
2. What are varicose veins and what causes them?
3. What is an electrocardiogram and when is it useful?
4. a. **Explain** why valves are important to the functioning of the heart.
   b. **Outline** how heart valves are similar to the valves in veins.
5. **Describe** how an electrocardiogram is used to detect heart abnormalities.

Apply and analyse

6. SI Look at the electrocardiograms in figure 3.57.
   a. At 'P', are the muscle cells of the atria contracted or relaxed?
   b. After the 'QRS' wave, is the ventricle relaxed or contracted?
   c. How does the normal electrocardiogram differ from the abnormal electrocardiogram?
   d. **Suggest** what might be wrong with the heart activity shown on the abnormal electrocardiogram.
7. SI **Construct** a matrix table to show the differences between red blood cells, HBOCs and PFCs.
8. a. **State** which organs are most successfully transplanted into humans.
   b. **List** sources of the organs for transplant and identify associated issues.
   c. **Describe** how donors and organ recipients are matched.
   d. Organ recipients can require specific treatment after the operation. **Outline** what this involves and why it is needed.
9. Dr Mary Kavurma and Dr Seana Gall are Tall Poppy Science Award winners. This award recognises young scientists who excel at research, leadership and communication. Dr Kavurma is a scientist at the University of New South Wales involved in research into atherosclerosis and cardiovascular disease. Dr Gall is based at the Menzies Research Institute, University of Tasmania, and her research field is cardiovascular epidemiology. **Explain** how advances in technology might have helped Dr Kavurma and Dr Gall better understand cardiovascular diseases.

Evaluate and create

10. SI a. If you required a new heart, would you prefer an artificial one or one from a human or other natural source? **Justify** reasons for your response.
    b. **Outline** your opinion on being an organ donor yourself.
11. SI Think about the different issues that might come up with the development and use of artificial blood. **Construct** a PMI chart to summarise these issues. Then share your opinion about artificial blood and explain why you feel that way.
12. SI Think about foods or drinks you know that are said to help reduce heart disease. Choose one and **construct** a SWOT diagram to evaluate its benefits and drawbacks. Then imagine you are part of a debate and write down what you would say to support your chosen food or drink.
13. SI Doctors use a stethoscope to listen to heartbeats. **Construct** and test your own stethoscope using rubber tubing and a plastic funnel.
14. SI Design an experiment to investigate the effect of different types of activities on your heart rate.
15. Think about the work and discoveries of Galen, Vesalius and Harvey. How do you think the times they lived in influenced their ideas and actions? Why do you think they refused to just accept the common beliefs of their times and instead asked questions? If you were living in their times, what question or hypothesis might you have asked?

Answers and sample responses are available in your digital formats.

LESSON 3.8 Respiratory system — breathe in, breathe out

LEARNING INTENTION

In this lesson you will describe the structure and function of the respiratory system.

3.8.1 Cells need energy!

Breathe in deeply … now breathe out. You have exchanged gases with your environment. You have supplied your body with some essential oxygen and removed some unwanted carbon dioxide. You do this about 15–20 times a minute without even having to think about it. Where does this oxygen go and where did the carbon dioxide come from?

Your cells need **oxygen** as it is essential for cellular respiration. This process involves breaking down **glucose** so that energy is released in a form that your cells can use. This reaction produces **carbon dioxide** as a waste product that needs to be removed.

glucose + oxygen → carbon dioxide + water + energy

Respiratory system

The main role of your respiratory system is to get oxygen into your body and carbon dioxide out. This occurs when you inhale (breathe in) and exhale (breathe out). The respiratory system is made up of your **trachea** (or windpipe) and your **lungs** (figure 3.61).

EXTENSION: Epiglottis

Wrong way, turn back! There is a flap of tissue at the top of the trachea called the **epiglottis**. This tissue's job is to stop food 'going down the wrong way'. If food does go the wrong way, a cough moves the food back up, to either be removed or travel its correct pathway — down your oesophagus to your stomach.

FIGURE 3.61 The epiglottis stops food from going down your trachea.

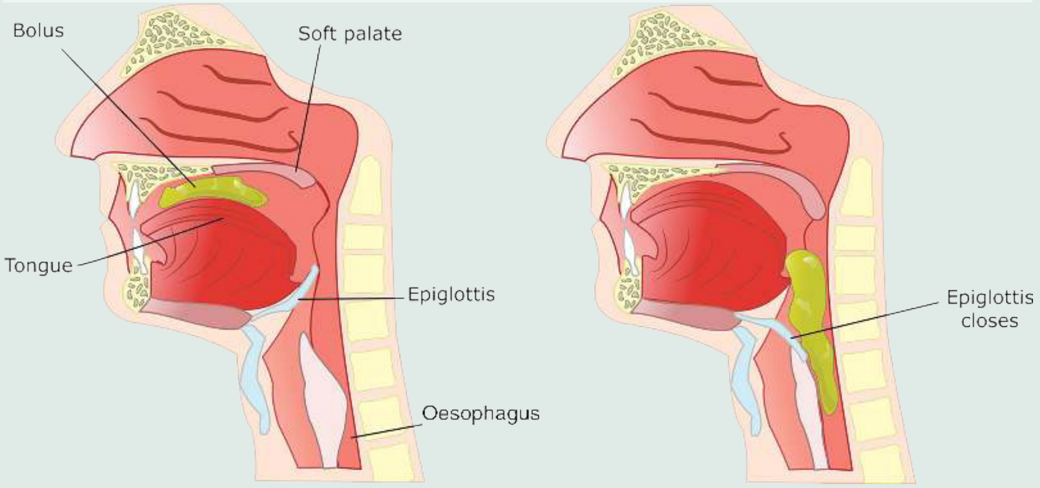
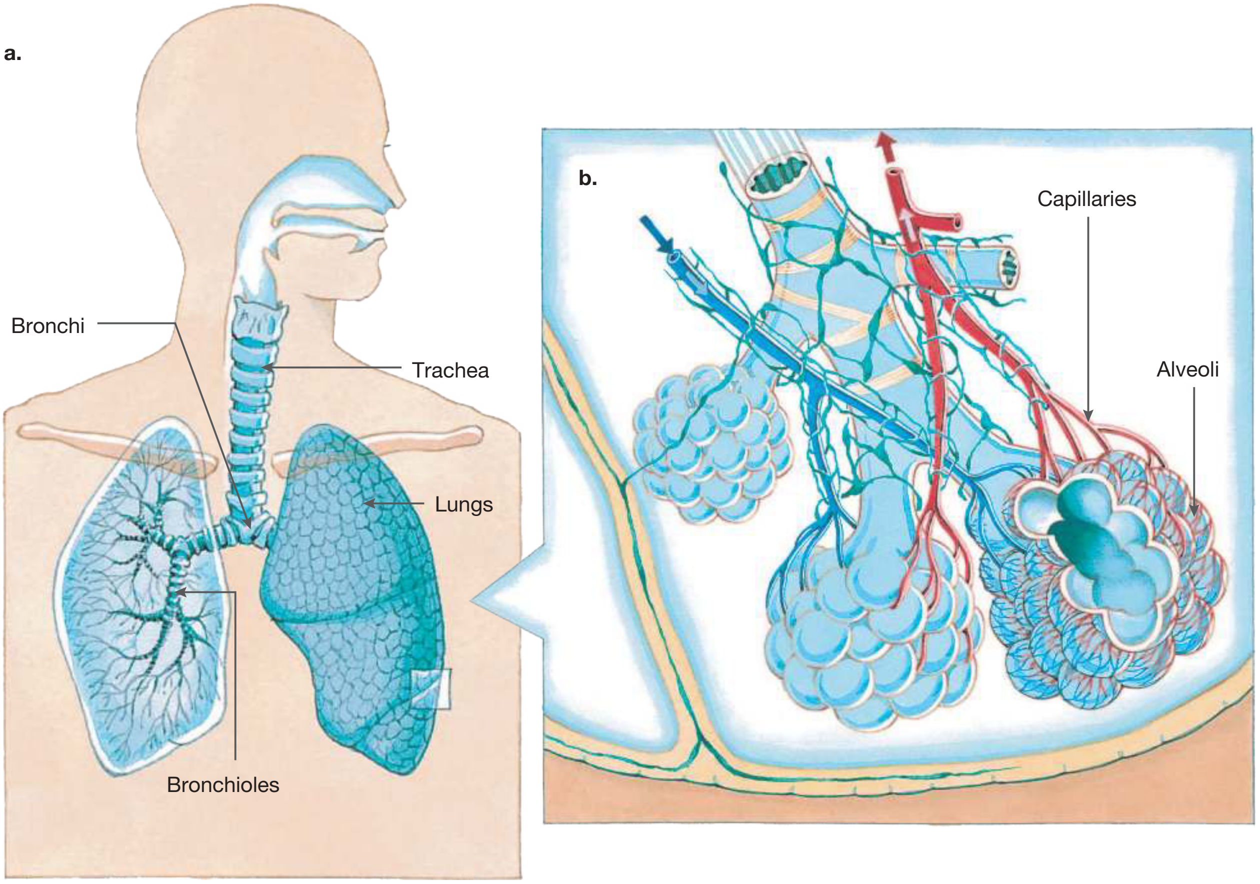


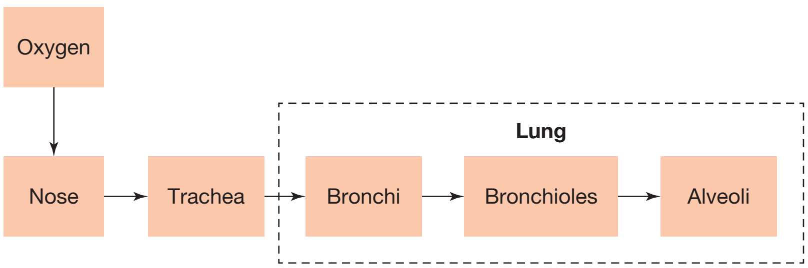
FIGURE 3.62 a. Organs of the respiratory system with **b.** a portion of the lung expanded to show details



Getting oxygen to your lungs

When you breathe in, air moves down your trachea, then down into one of two narrower tubes called **bronchi** (bronchus). After that, the air moves into smaller branching tubes called **bronchioles**, which end in tiny air sacs called **alveoli** (alveolus) (figures 3.62 and 3.63). It is at the alveoli that gases (such as oxygen and carbon dioxide) are exchanged between the respiratory system and the circulatory system.

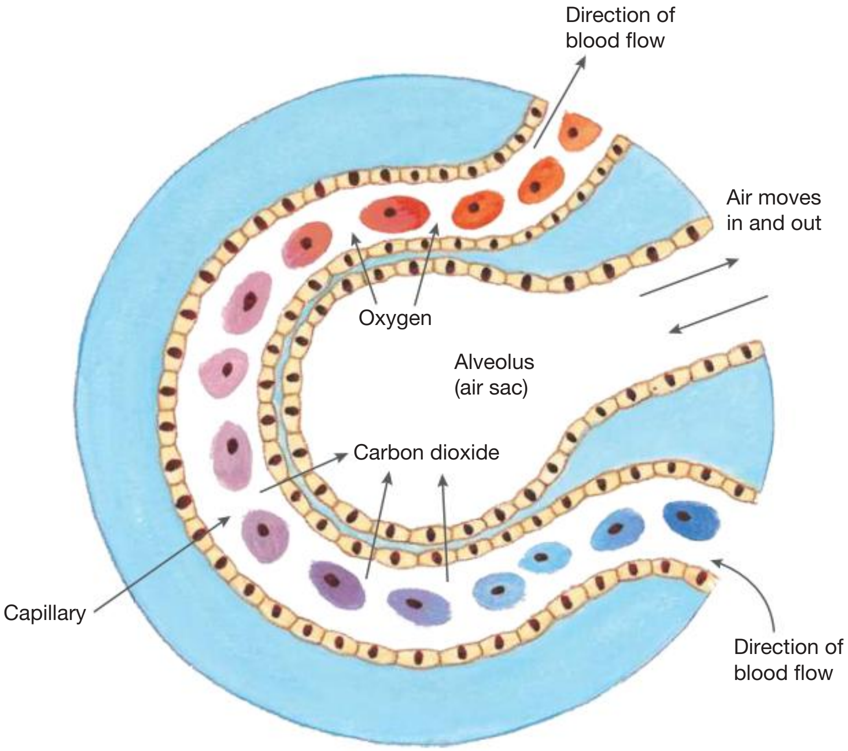
FIGURE 3.63 The pathway oxygen travels to your lungs when you inhale



3.8.2 Working together to get oxygen from lungs to cells

Your circulatory and respiratory systems work together to get oxygen to your cells. Once you have breathed in and oxygen has reached your alveoli, oxygen diffuses into red blood cells in capillaries that surround the alveoli (figure 3.64).

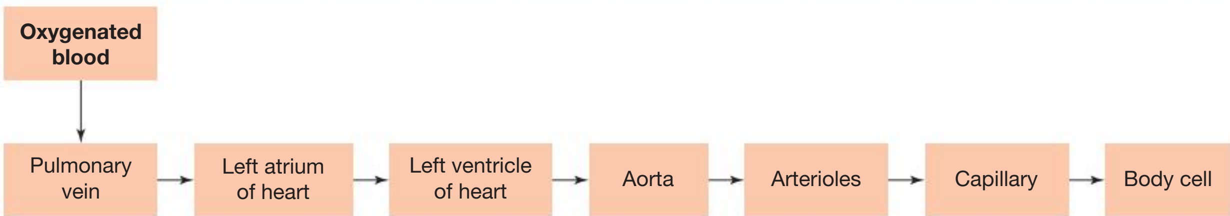
FIGURE 3.64 In an alveolus, oxygen diffuses into the blood and carbon dioxide diffuses out of the blood.



The oxygen diffuses into the red blood cells because there is a higher concentration of oxygen inside the alveoli than inside the blood cells. Once inside the red blood cells, oxygen binds to haemoglobin to form oxyhaemoglobin. It is in this form that oxygen travels throughout your body. The blood that it travels in is referred to as oxygenated blood.

In figure 3.65, the oxygenated blood travels from your lungs via the **pulmonary vein** to the left atrium of your heart. From here, it travels to the left ventricle where it is pumped under high pressure to your body through a large artery called the **aorta**. The oxygenated blood is then transported to smaller vessels (**arterioles**) and finally to capillaries, through which it diffuses into body cells for use in cellular respiration.

FIGURE 3.65 The pathway oxygen travels from your lungs to your body cells



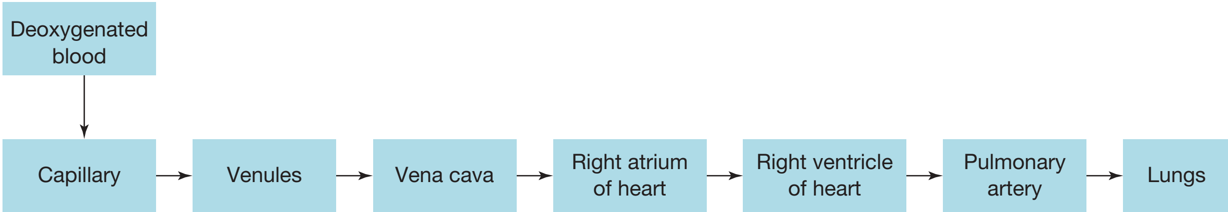
CASE STUDY: Garlic breath

Ew … garlic breath! Have you ever heard someone say this? Garlic or onion breath comes from further down than your mouth! It has travelled through a number of your body systems. After you have eaten food containing either of these, and it has been digested, it is absorbed through the walls of your intestines and then into your blood. When the smelly onion or garlic blood reaches your lungs through your circulatory system, you breathe out the smelly gas.

3.8.3 Working together to get carbon dioxide from cells

Carbon dioxide is a waste product of cellular respiration and needs to be removed from the cell. When carbon dioxide has diffused out of the cell into the capillary, the blood in the capillary is referred to as deoxygenated blood. This waste-carrying blood is transported from the capillaries to small veins (**venules**) then to increasingly larger veins, until it enters the two largest veins, the superior and inferior vena cava, which deliver blood to the right atrium of your heart. From here it travels to the right ventricle, where it is pumped to your lungs through the **pulmonary artery** (the only artery that does not contain oxygenated blood). This process is shown in figure 3.66.

FIGURE 3.66 The pathway carbon dioxide travels from your body cells to your lungs



Exhaling carbon dioxide from lungs

Once the deoxygenated blood reaches the alveoli of the lungs, carbon dioxide diffuses out of the capillaries. This occurs because there is a higher concentration of carbon dioxide inside the capillaries than in the alveoli. Carbon dioxide is then transported into the bronchiole, then bronchi and trachea, until it finally exits through your nose (or mouth) when you exhale, as seen in figure 3.67.

FIGURE 3.67 The pathway carbon dioxide travels from your lungs to be exhaled

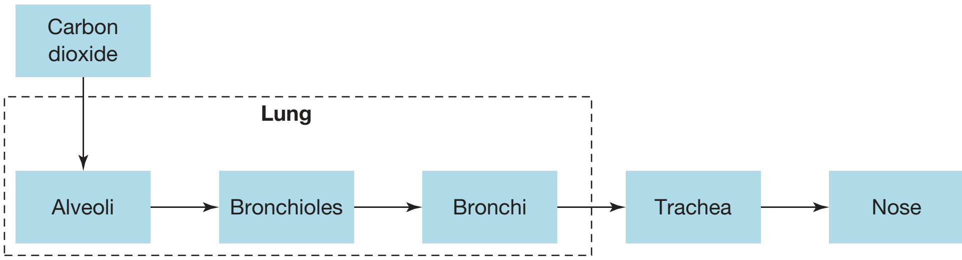
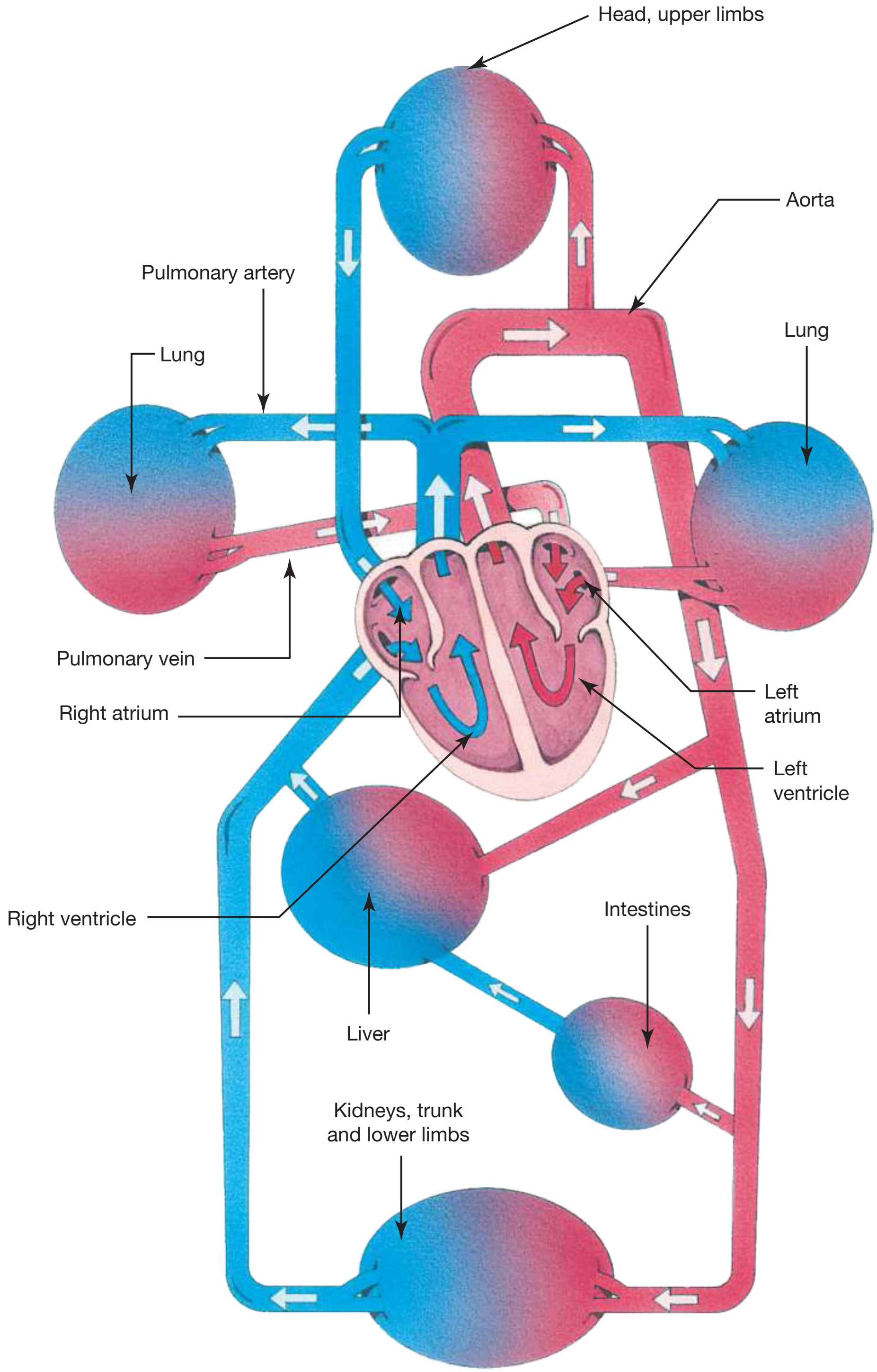


FIGURE 3.68 Your respiratory, circulatory and digestive systems form connected highways that provide your cells with what they need and remove what they don't.

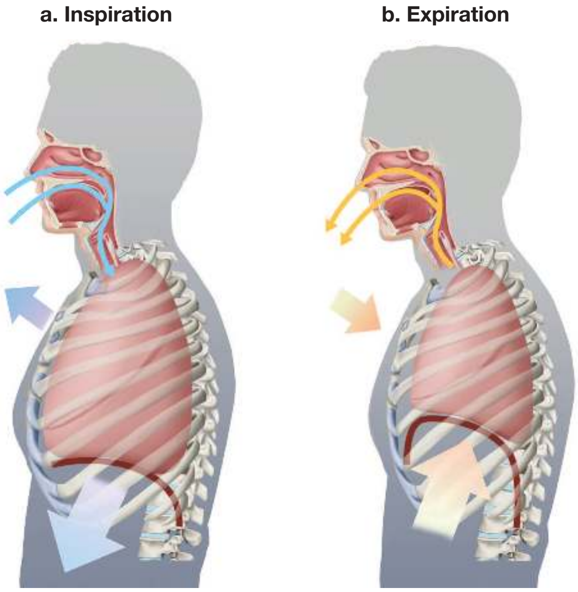


3.8.4 Brain AND muscle?

The respiratory system also relies on organs from other systems. Figure 3.69 shows that when you breathe in, a muscle tightens beneath your rib cage. This muscle is called the **diaphragm**. It allows the lungs to expand and air to be pulled into them. When you breathe out, the diaphragm relaxes, which reduces the size of the lungs and pushes air out. The largest volume of air that you can breathe in or out at one time is called your **vital capacity**.

Breathing involves muscle movements that are automatic and controlled by the brainstem. The brainstem is the part of the brain that controls subconscious body functions such as breathing and heart rate.

FIGURE 3.69 When you breathe in, your diaphragm tightens; when you breathe out, it relaxes.

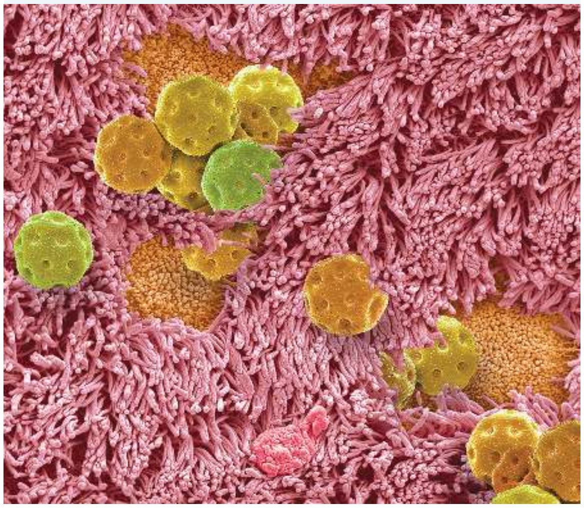


3.8.5 Cleaning the air

The surfaces of the upper respiratory tract are covered in cilia. These hair-like projections work to move the mucus that also covers these membranes up and out of the airway. This is a vital process in protecting the body against pathogens, pollen and particulates such as smoke. The items get trapped in the mucus before they can enter the cells of the respiratory tract, thus preventing disease.

Mucus from the lungs is transported back up the trachea and is swallowed, where the acids of the stomach can kill anything harmful. This also occurs with mucus produced in the nose, unless you blow your nose!

FIGURE 3.70 Cilia of the nose with inhaled pollen



INVESTIGATION 3.8

Hands on pluck

Aim

To investigate the trachea, lungs, heart and liver of a mammal

Materials

- sheep's pluck (heart and lungs) with part of the liver and trachea attached
- newspaper and tray to place the pluck on
- plastic disposable gloves
- balloon pump and rubber tubing

Method

1. Carefully observe and record the shape, size, colour and texture of the sheep's trachea, lungs, heart and liver. Include notes on how they are connected. Can you see any blood vessels?
2. Push a piece of rubber tubing down the trachea to the lungs and use a balloon pump to blow some air into the trachea.

CAUTION: For hygiene reasons, do not use your mouth to blow into the tube inserted in the trachea.

3. Cut through the lung, heart and liver tissue. Make a record of your observations describing how they are similar and how they are different. Discuss possible reasons for the differences with your team members.
4. Using a scalpel or scissors, cut off a small piece of heart, lung and liver. Place each piece into a beaker of water and observe what happens. Discuss possible reasons for your observations with your team members.

Results

Record observations in the table provided.

Organ	Shape (sketch)	Approx. size (cm)	Colour	Texture	Other comments	System to which the organ belongs
Trachea						
Lung						
Heart						
Liver						

Discussion

1. Could you see any blood vessels? Try to find out their names and what sort of blood they carry.
2. Suggest why there are rings of cartilage around the trachea.
3. Suggest reasons for the differences in texture between the heart and lungs.
4. Suggest reasons for the differences in the shapes of the organs that you observed.
5. Comment on something that you learned or found particularly interesting from this investigation. Share your comment with others.
6. Research and report on the following points for each of the organs in this investigation:
   - Its function and how it carries this out
   - The system to which it belongs
   - A disease relevant to it.

Conclusion

Summarise the findings for this investigation.

INVESTIGATION 3.9

Measuring your vital capacity

Aim

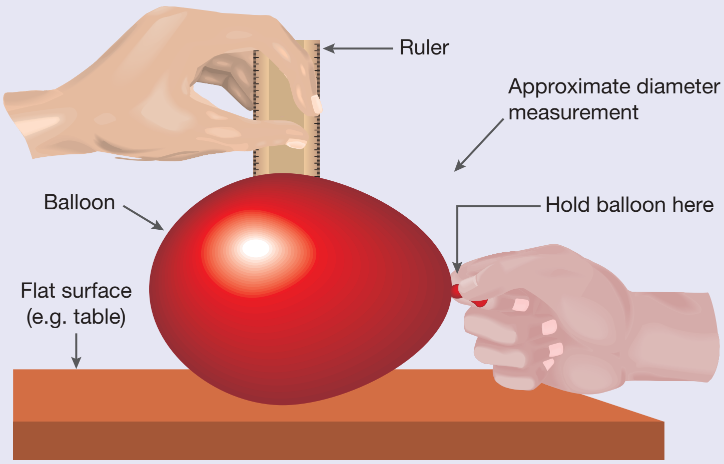
To investigate the vital capacity of lungs

Materials

- balloon
- ruler

Method

1. Blow up a balloon to about 20 cm in diameter two or three times to stretch it. Release the air each time.
2. Take the biggest breath you can, then blow out all the air into the balloon. Tie up the end of the balloon to hold in your 'blown out' air.
3. Use a ruler to measure and record the diameter of the balloon as shown in the following figure.



4. Use the following table to determine your approximate vital capacity in litres.
5. Release the air from the balloon and repeat your measurement of vital capacity three more times. Average your results to get your best estimate of the maximum 'blow-out' of your lungs.

Balloon diameter (cm)	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Approx. vital capacity (L)	0.3	0.4	0.5	0.7	0.9	1.2	1.4	1.8	2.1	2.6	3.0	3.6	4.2	4.8

Results

1. Draw a table with the following headings.

Name	Male or female?	Does this student play a wind instrument?	Lung capacity (L)

2. Collect results from all the students in your class and complete the table.
3. Calculate the average lung capacity for all the females and for all the males in your class.
4. Calculate the average lung capacity for all students in your class who play a wind instrument.

Discussion

1. Suggest why you were asked to stretch the balloon first.
2. Suggest why you measured your vital capacity four times.
3. With reference to your results, do females have a bigger or smaller lung capacity than males in your class?
4. Compare the average lung capacity for students who play a wind instrument with the average value for students who do not. Do your results suggest that playing a wind instrument has an effect on lung capacity? Explain.
5. Reflect on the method used to investigate vital capacity and identify improvements that could be made if you were to do the investigation again.

Conclusion

Summarise the findings for this investigation.

3.8 Activities

learnon

3.8 Quick quiz (on)	3.8 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 5, 11	2, 6, 8, 9	3, 7, 10, 12

Remember and understand

1. a. **State** whether the following statements are true or false.

Statement	True or false?
i. Body cells need oxygen for the process of cellular respiration.	
ii. The process of cellular respiration produces energy in a form that the cell can use and oxygen is a waste product.	
iii. The role of the respiratory system is to get carbon dioxide into your body and oxygen out.	
iv. The respiratory system is made up of your oesophagus and your lungs.	
v. Oxygen diffuses from the alveoli into red blood cells in capillaries that surround them.	

b. Rewrite any false responses.

2. Match the terms associated with the respiratory system with their description in the table shown.

Term	Description
a. Alveoli	A. Blood vessel that carries deoxygenated blood from the heart to the lungs
b. Bronchiole	B. One of two narrower tubes that leads off the trachea
c. Bronchus	C. A muscle that allows the lungs to expand so that air can be pulled in
d. Diaphragm	D. A red pigment that binds to oxygen
e. Haemoglobin	E. Blood vessel that carries oxygenated blood from the lungs to the heart
f. Pulmonary artery	F. Tube through which air moves from your mouth to your lungs
g. Pulmonary vein	G. Tiny air sac through which oxygen diffuses into capillaries
h. Trachea	H. Small branching tube with alveoli at its end

3. Use flowcharts to **identify** the pathway that:
   a. oxygen travels to get from the air outside your body to the alveoli of your lungs
   b. oxygen travels to get from your lungs to your body cells
   c. carbon dioxide travels to get from your body cells to the alveoli of your lungs
   d. carbon dioxide travels to get from your lungs to the air outside your body.
4. **Describe** how oxygen gets from the alveoli of your lungs into blood cells in your capillaries.
5. Differentiate between the terms 'cellular respiration', 'respiratory system' and 'breathing'.

Apply and analyse

6. Some people describe the structure of the lungs as an upside-down hollowed-out tree. To which parts of the lungs might the following be referring?
   a. Trunk
   b. Branches
   c. Twigs
   d. Leaves
7. Give reasons for the following pieces of advice.
   a. It is better to breathe through your nose than your mouth.
   b. You should blow your nose when you have a cold rather than sniff it back.
   c. You should not talk while you are eating or drinking.
8. SI The following table shows approximate percentages of various gases breathed in and breathed out.

	Oxygen (%)	Carbon dioxide (%)	Water vapour (%)	Nitrogen (%)
Air breathed in	21	0.04	1	78
Air breathed out	15	4	5	76

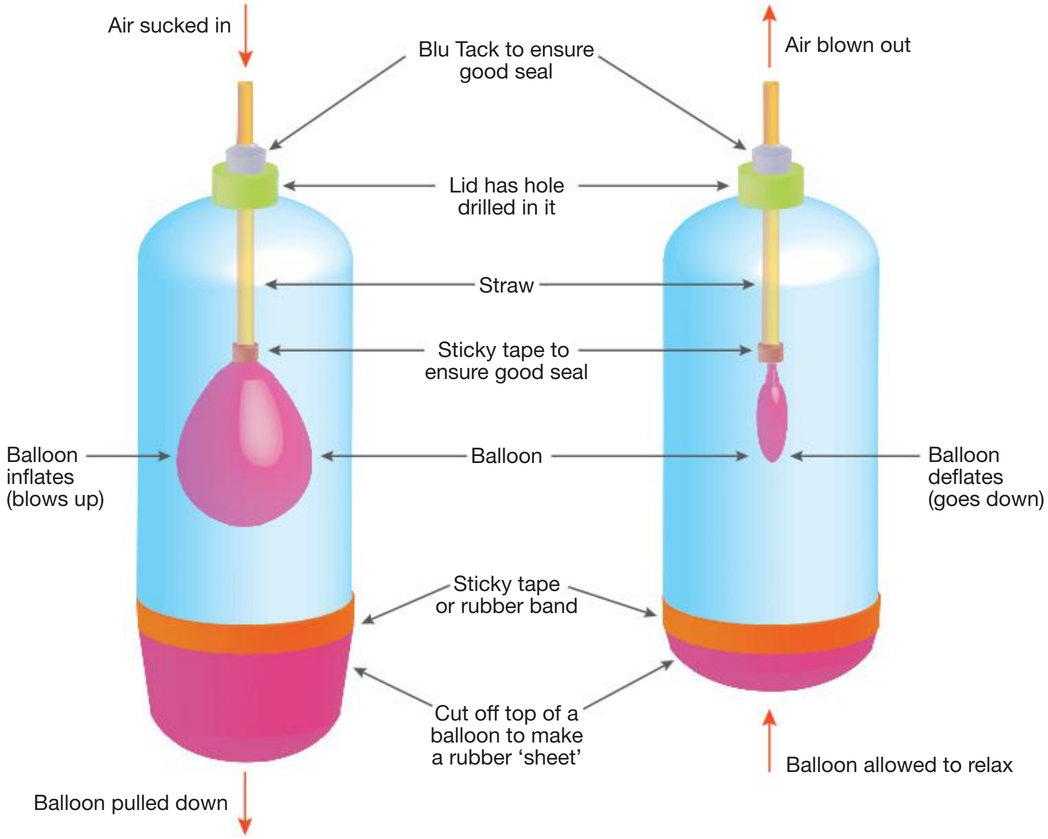
   a. i. **Compare** the percentage of oxygen breathed in to that breathed out.
      ii. **Suggest** a reason for this pattern.
   b. i. **Compare** the percentage of carbon dioxide breathed in to that breathed out.
      ii. **Suggest** a reason for this pattern.
9. Some singers can hold a musical note for a very long time. **Suggest** what muscles and techniques you think are used to be able to do this.
10. Did you know that mountain climbers often find it difficult to breathe? Some wear oxygen tanks to allow them to climb very high mountains. **Discuss** why you think this is necessary at high altitudes.

Evaluate and create

11. Relate structural features to the functions of the following parts of the respiratory system.

Part of respiratory system	Structural features	Function
Trachea		
Alveoli		
Lungs		
Capillaries		

12. SI **Construct** a model lung as shown in the diagram. You can use the following items:
- Two clear 1-litre plastic bottles with tops
- Four balloons
- Two plastic drinking straws
- Rubber bands or very sticky tape
- Plasticine or Blu Tack
- Scissors.



a. **Identify** which body parts are represented in the model lung by the:
   i. straw
   ii. rubber sheet at the bottom of the bottle
   iii. balloon connected to the straw
   iv. plastic bottle.

b. Pull the rubber sheet at the bottom of your model downwards. Record your observations. Release the rubber sheet. Record your observations. **Discuss** how your observations relate to how a lung works. **Suggest** how the model could be improved.

Answers and sample responses are available in your digital formats.

LESSON 3.9 Short of breath?

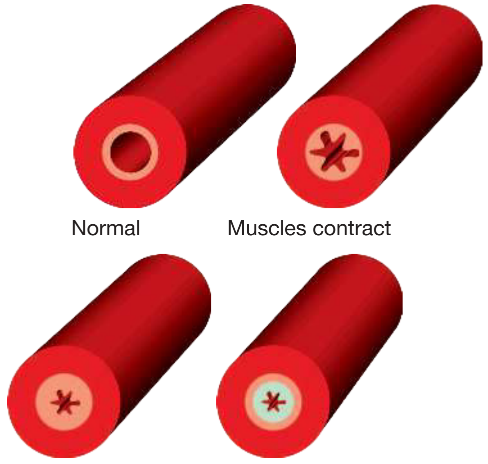
LEARNING INTENTION

In this lesson you will describe examples of illnesses and problems associated with the respiratory system.

3.9.1 Asthma

If you do not suffer from **asthma**, it is very likely that you know someone who does. Asthma is a very common condition and the number of people who suffer from it has increased over the years.

FIGURE 3.71 Asthma is a narrowing of the air pipes.



What is asthma?

Asthma is a narrowing of the air pipes that join the mouth and nose to the lungs. The pipes most affected are the bronchi. They become narrower as:

- the muscle walls of the air pipes contract
- the lining of the air pipes swells
- too much mucus is produced.

The narrow pipes make breathing difficult and can result in wheezing, coughing and a tight feeling in the chest. The coughing is usually worse at night.

What causes asthma?

It is not known why some people get asthma and others do not. It seems that it can be inherited, but many people from families without a history of asthma are affected. Asthma is certainly the result of sensitive airways. An asthma attack occurs when those sensitive airways are 'triggered'. If the sufferer has a cold, the airways are already inflamed and are more likely to be triggered.

Some of the common triggers of an asthma attack are:

- vigorous exercise
- cold weather
- cigarette smoke
- dust and dust mites
- moulds
- pollen
- air pollution
- some foods and food additives
- some animals.

Not all asthma sufferers are affected by the same triggers. Some people suffer attacks only as a result of exercise. Others might be affected by any one or more of the triggers. It is important that those who get asthma try to find out what triggers the attacks. Many of the triggers can be avoided.

Controlling the triggers

The best way to control asthma is to avoid the triggers. While this is not always possible, it is worthwhile to recognise the triggers so that you can minimise them.

Pollen and moulds

Pollen from some grasses and trees is very light and becomes airborne on even slightly windy days. The inhaling of pollen can be reduced by avoiding outdoor activities and keeping windows and doors closed on breezy spring days. Moulds live in warm, humid conditions and thrive in bathrooms, kitchens and bedrooms. Their spores are easily breathed in, triggering attacks in some asthma sufferers. Moulds can be reduced by airing the house regularly.

Air pollution

Those asthma sufferers whose attacks are triggered by air pollution are warned to remain indoors as much as possible and avoid vigorous activity on smoggy days. If tobacco smoke is a trigger, the cigarette smoke of others needs to be avoided.

Dust mites

Dust mites are tiny creatures that can cause asthma attacks. They live in warm, moist and dark places such as beds, pillows, carpets and curtains. Their droppings float in the air and can be easily breathed in.

FIGURE 3.72 A house dust mite

The most common dust mite in Australia is called *Dermatophagoides pteronyssinus*. It is very small, about half a millimetre long, and does not bite. However, there can be thousands of them in your pillow, each producing about 20 droppings a day, laying eggs, and eventually dying and decomposing. They even mate for 24 hours straight!

Dust mites feed on our dead skin cells, so they are always around us. Dr. Janet Rimmer from the National Asthma Council Australia says that about 80 per cent of Australians with allergies are allergic to dust mites. Dr. Matthew Colloff, a CSIRO researcher, found them so interesting that he wrote a book about them.

Even the cleanest houses have dust mites, but you can reduce their numbers by:

- putting your mattress in the sun to dry out the mites
- washing bedding and clothes with tea-tree or eucalyptus oil, or in hot water (above 55 °C)
- removing or washing soft toys weekly
- vacuuming curtains and carpets regularly
- keeping doors and windows open to air out rooms
- replacing carpets with hard flooring.

EXTENSION: Shedding our skin

Dust mites thrive best in bedding and carpets because these contain plenty of human dead skin cells. Humans shed a complete layer of dead skin cells every month. That amounts to about 1 kg of skin cells each year. In fact, most of the dust in your house consists of dead skin cells.

Asthma medication

Asthma medications can be divided into two main groups: preventers and relievers. Preventers make the lining of the airways less sensitive and therefore less likely to be triggered. Relievers open up the airways once an attack has commenced. Most asthma medications are applied with inhalers or ‘puffers’, as seen in figure 3.73, which direct the medication straight into the lungs for fast action. Severe attacks of asthma require other drugs and sometimes extra oxygen needs to be supplied.

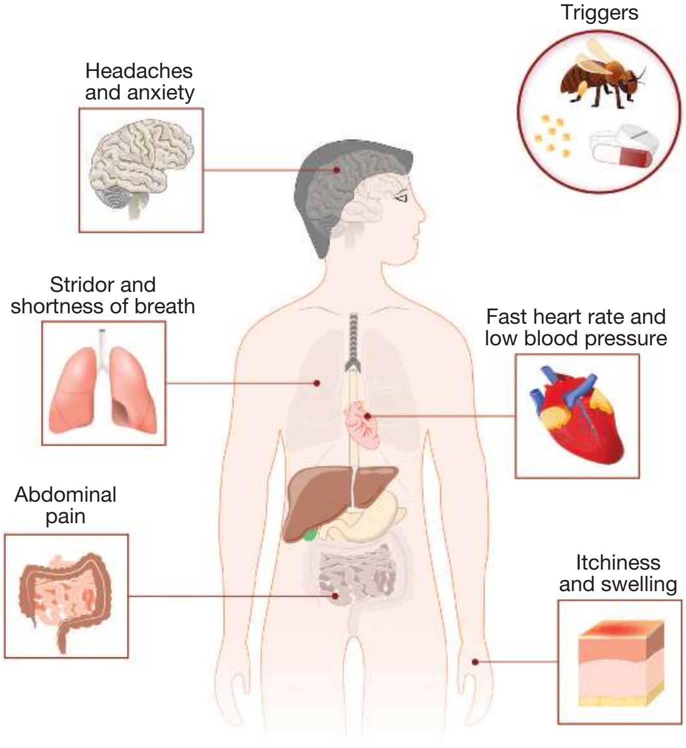
FIGURE 3.73 Asthma medication is usually delivered through an inhaler.

3.9.2 Allergies

Allergies can also trigger a response in the airways. Allergies occur when the body responds to a harmless substance as if the substance is harmful. Common substances that cause reactions are called **allergens** and include pollen (causing hayfever), animal dander, dust mites, insect bites or stings, as well as some foods — particularly nuts, shellfish, eggs and milk.

Sometimes allergies can result in hives, itchy and watering eyes, or a runny or blocked nose. If the reaction is severe, parts of the respiratory system may swell. A severe reaction is called **anaphylaxis** and may cause death.

FIGURE 3.74 The symptoms of anaphylaxis



As the parts of the respiratory system swell, it becomes harder for the sufferer to get oxygen into their body. The treatment for anaphylaxis is an injection of adrenaline via an EpiPen.

3.9.3 Smoking and vaping

Asthma is not the only condition that can interfere with your lungs functioning as they should. Some human activities can damage not only your lungs, but also those of others around you. Smoking and vaping are two examples of such an activity. About 20 500 Australians die each year as a result of diseases caused by smoking (figure 3.75). Smoking is actually the largest preventable cause of death and disease in Australia.

Just one cigarette

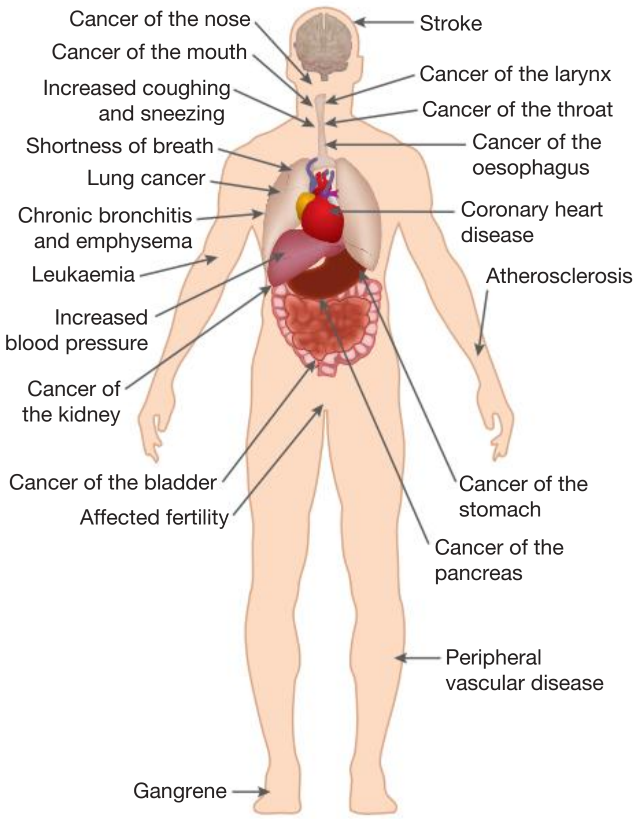
There are clearly many long-term effects of smoking. However, figure 3.76a shows what happens to you after smoking just one cigarette.

There are some more obvious effects such as bad breath, body odour and watery eyes. After several cigarettes, your teeth and fingers become stained. Your sense of taste is reduced. Even your stomach is affected as acid levels increase.

Smoking and your lungs

Lung cancer is the most well-known disease caused by smoking. Chemicals that cause cancer are called **carcinogens**. Cigarette tobacco contains a number of carcinogens. The chemicals in cigarettes also clog up the fine hairs in your air tubes with a mixture of mucus and foreign chemicals.

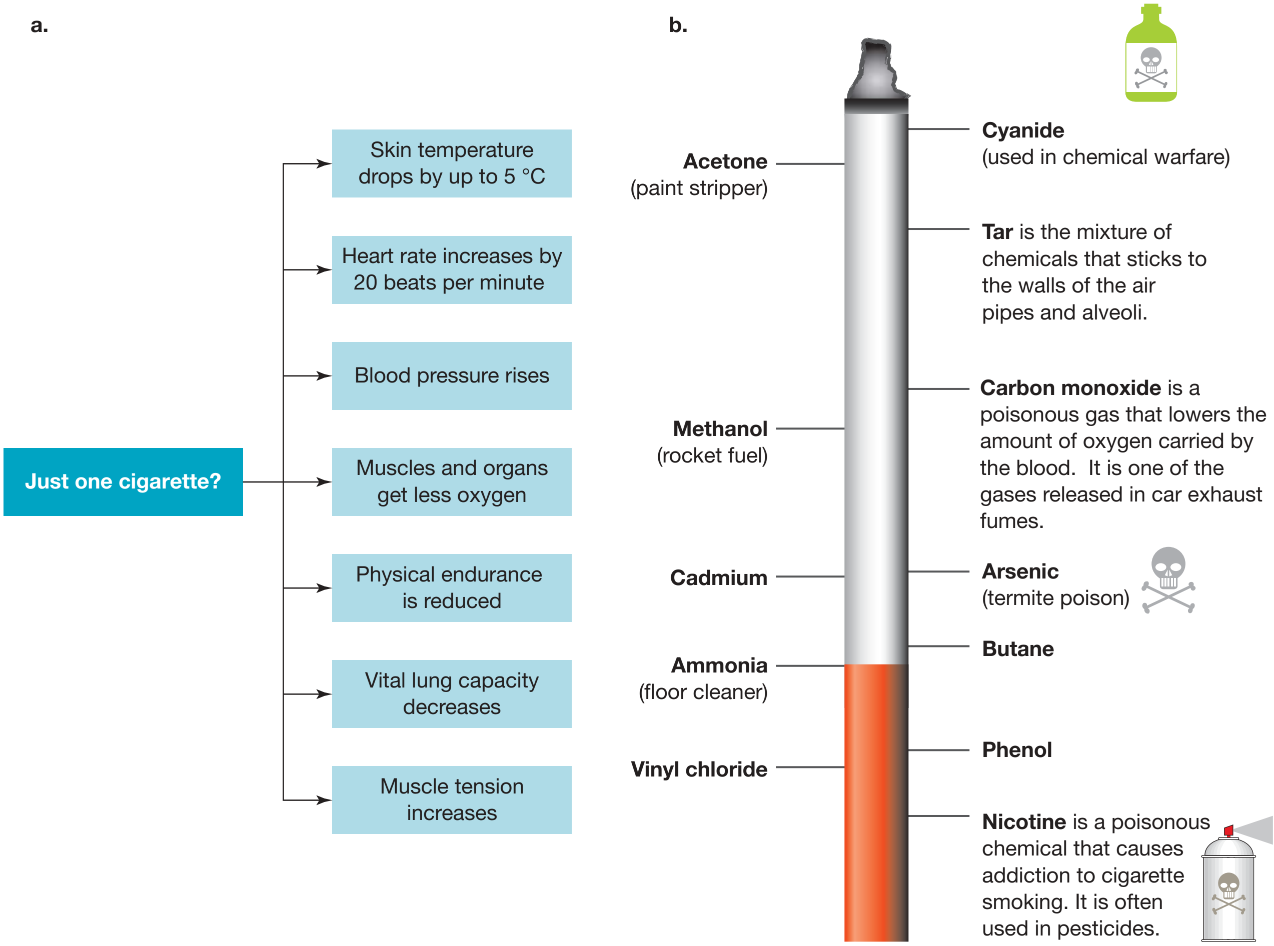
FIGURE 3.75 With over 4000 chemicals in each cigarette, smoking can lead to any of these conditions and effects.



Cough it up

Coughing is the body's way of trying to clear the air tubes. However, not all of the clogging can be cleared by coughing. A dirty mixture remains in the air tubes, causing swelling, making them sensitive and slowing down the passage of air. Eventually, the sticky mixture sinks down into the lungs where it blocks some of the pathways to the alveoli, where freshly breathed air should deliver oxygen to the blood.

FIGURE 3.76 a. The results of just one cigarette b. What is in a cigarette?



The diseases caused by this blocking process are called chronic obstructive pulmonary diseases, or COPD. **Emphysema** is the worst of these diseases and results in the eventual destruction of the alveoli.

Vaping — do not be fooled

Vaping is the inhaling of a substance that has been heated and turned into a vapour. These substances generally contain water, flavours, solvents and nicotine. The obviously harmful chemical in this list is the nicotine — but this isn't the whole story. Along with nicotine (which has been found in vapours that are supposedly nicotine-free) there may be:

- ultra-fine particles that get inhaled deep into the lungs and stay there
- flavourants that have been linked to lung disease
- volatile organic compounds (phenol and toluene are two examples also found in cigarettes)
- heavy metals such as nickel, tin and lead.

This means that vaping is almost as harmful as smoking a regular cigarette. Vaping has been linked to a number of deaths from acute lung disease. This was linked to a compound in e-cigarettes that is safe if ingested, but toxic if inhaled.

Short-term and medium-term effects of vaping have been seen in the lungs and hearts of those who vape, including a higher prevalence of asthma, emphysema and chronic bronchitis. Longer term effects, such as a relationship to cancer, are still being studied, as this is a relatively new technology.

SCIENCE AS A HUMAN ENDEAVOUR: Professor Robyn O'Hehir BSc, MBBS (Hons I), FRACP, PhD, FRCP, FRCPath

- **What is your current science-related title?**
  I am a Professor of Medicine, with particular responsibilities for allergy, clinical immunology and respiratory medicine, at Monash University, Melbourne. I am also the Director of the Department of Allergy, Immunology and Respiratory Medicine at the Alfred Hospital in Melbourne.
- **What field of science are you in?**
  Allergy, cellular immunology and respiratory medicine. I was appointed to the first Chair in Allergy and Clinical Immunology in Australia.
- **Describe some science that you are involved in at the moment.**
  Millions of people around the world suffer from allergies. I am sure you know several friends who have asthma or hay fever, or you may even have them yourself. Asthma and hay fever are usually triggered by proteins called allergens, from house dust mites or grass pollens. Allergies to peanuts and shellfish are less common but often more serious, because they can trigger life-threatening allergic reactions called anaphylaxis. Allergies are caused by reactions between white blood cells ('T cells') and environmental proteins that are usually harmless. My research group is trying to find ways to damp down the allergic T-cell responses.

  Allergen immunotherapy (allergy shots) is the only treatment that can prevent allergic diseases, but currently it can't be used for peanut allergies, even though this is one of the most serious allergens. To develop a safe and effective vaccine against peanut allergies, we are identifying parts of critical peanut proteins that can build up tolerance in allergic patients without risking anaphylaxis.
- **What do you enjoy about being a scientist?**
  I enjoy the fact that my research not only is laboratory-based, exploring novel methods for switching off allergic responses, but also lets me see patients and train other doctors in how to do research from bench to bedside to the community. I head an active clinical department, still carry out clinics with patients and am actively engaged in national and international tests of new preventions and treatments for allergies. My combined research and clinical duties allow translation of our research findings into better clinical practice.
- **What triggered your interest in science?**
  I decided to specialise in allergy and respiratory medicine, focusing on asthma, following my experiences as a young trainee physician at the Alfred Hospital in Melbourne. Asthma was a huge problem in Australia at that time, and many times I resuscitated young adults in the hospital emergency room — and I watched them return, with appropriate medication and careful education, to confident, full lives. Some remain my patients today. The ability to dissect underlying mechanisms of disease and then work towards new therapeutics and practices to benefit patients is a great excitement and honour. The diversity of patients and their needs ensures that every day is quite different.
- **Do you have any other comments that may be of interest to Year 8 Science students?**
  A career in science combined with medicine may take a bit longer in terms of training, but it gives you a fantastic ability to do interesting work that is intellectually demanding and also involves working with lots of people who need your help. I am very glad that I chose a career in science and medicine.

1. Professor O'Hehir's research focuses on creating vaccines for serious allergies, such as peanut allergies. How could developing a safe vaccine for peanut allergies improve the lives of individuals and their families? What social and economic benefits might arise from such a breakthrough?
2. Professor O'Hehir's work bridges laboratory research and clinical practice, helping patients directly. Why do you think it is important for scientists and doctors to work together to solve health problems? How might this approach improve treatments for allergies and other diseases?

Proposed scientific responses to socio-scientific issues impact on society and may involve ethical, environmental, social and economic considerations (VC2S8H03)

3.9 Activities

learnon

3.9 Quick quiz on	3.9 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 3, 6, 8	2, 4, 9, 10	5, 7, 11, 12, 13

Remember and understand

1. a. **State** whether the following statements are true or false.

Statement	True or false?
i. Asthma is a rare condition and the number of people suffering from it has decreased in the past 50 years.	
ii. Asthma is a narrowing of the air pipes that join the mouth and nose to the lungs.	
iii. The tubes most affected by asthma are the bronchi.	
iv. Breathing can be restricted during an asthma attack due to swelling of the bronchi.	
v. All asthma sufferers are affected by the same triggers.	
vi. Fungal spores from moulds can be a trigger for asthma attacks.	
vii. Fewer asthma attacks are likely to occur on a windy day than on a day without wind.	
viii. Dust mites are a common trigger for asthma attacks.	
ix. Asthma medications may be classified as being preventers if they make the lining of the airways more sensitive.	
x. Asthma medications may be classified as being relievers if they open up the airways once an attack has commenced.	
xi. Smoking just one cigarette may increase your blood pressure.	
xii. There is no link between smoking and lung cancer.	
xiii. Chemicals in cigarettes can block some of the pathways to the alveoli in your lungs, which can reduce the amount of oxygen delivered to your cells.	

   b. Rewrite any false responses.
2. a. **Describe** what happens to the air pipes during an asthma attack to make breathing difficult.
   b. **Explain** why an asthma attack is more likely to be triggered in a person with a cold.
   c. **Define** an asthma trigger.
   d. **Identify** the two major types of asthma medication and how are they different from each other.

Apply and analyse

3. Create a poster that sends one single important message about smoking or vaping.
4. **Explain** what an EpiPen is and how it is used.
5. SI Brainstorm ideas about the common triggers of asthma that can be controlled. **Summarise** your discussion in a bubble map.
6. SI a. If you suffer from asthma, prepare a talk for the rest of your class explaining:
      i. what it is
      ii. how it affects you
      iii. how you control it or try to prevent attacks.
   b. If you do not suffer from asthma, write a set of at least five questions that you could ask an asthma sufferer in an interview. If possible, conduct the interview and record the answers in writing, or as audio or video.

7. a. **Describe** the structure and function of an alveolus.
   b. **Suggest** how the structure of an alveolus is related to its function.
   c. **Suggest** how smoking affects the ability of an alveolus to perform its function.

Evaluate and create

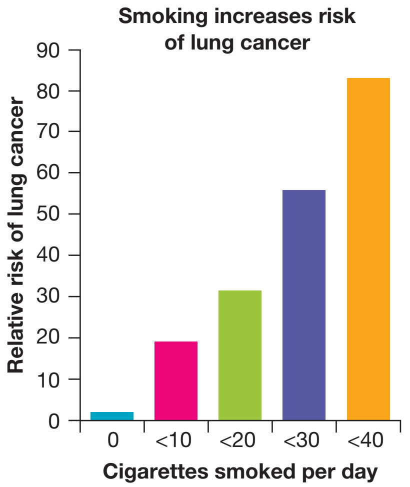
8. SI **Construct** a two-column table. The first column should be headed 'Reasons for smoking/vaping'; the second column should be headed 'Reasons for not smoking/vaping'. Complete the table.
9. SI Smoking-related diseases cost taxpayers many millions of dollars because hospitals are mostly paid for by governments. Write down your opinion of each of the proposals given. Give reasons for your opinion.
   a. The cost of hospital treatment for diseases caused by smoking should be paid for by the patient because it was their fault that they got sick.
   b. Cigarettes should cost more. The extra money made from them could then be given to hospitals to help pay for treating smoking-related diseases.
   c. Cigarette companies who make profits from smoking should be made to pay for hospital treatment of patients with diseases caused by smoking.
10. SI The following table shows how the popularity of smoking has changed over a period of around 70 years.

Year	1945	1964	1969	1974	1976	1980	1983	1986
Adult Australian males who smoke (%)	72	58	45	41	40	40	37	33
Adult Australian females who smoke (%)	26	28	28	29	31	31	30	28

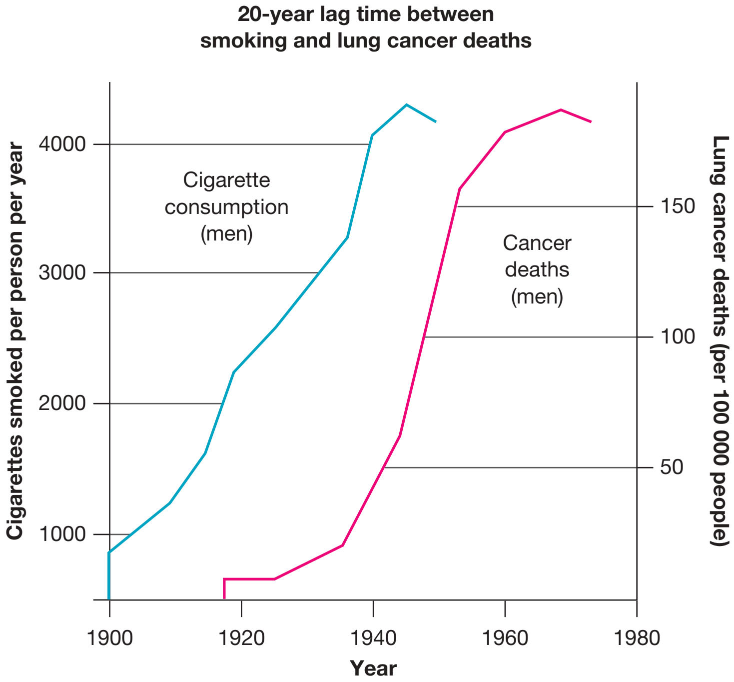
Year	1989	1992	1998	2001	2004	2011	2014	2017
Adult Australian males who smoke (%)	30	28	29	28	26	18.2	16.9	16.5
Adult Australian females who smoke (%)	27	24	24	21	20	14.4	12.1	11.1

   a. **Construct** a line graph of the data in the table. Use 'Year' on the *x*-axis and '% of adult Australians who smoke' on the *y*-axis. Draw lines for males and females in different colours.
   b. **Suggest** why you think the percentage of females who smoke changed little while the percentage of males declined greatly.
   c. Use dotted lines to show your prediction of the trends up to the year 2030. What percentage of males and females do you predict will be smoking in 2030?

11. SI Study the graph provided, which shows that the risk of getting lung cancer increases with the number of cigarettes smoked daily.
   a. Copy and complete the following statements.
      i. People who smoke 10 cigarettes a day are ____________ times more likely to develop lung cancer than non-smokers.
      ii. People who smoke 30 cigarettes a day are _____________ times more likely to develop lung cancer than people who smoke 10 cigarettes a day.
   b. If a packet of 20 cigarettes costs $30, **calculate** how much a person smoking 40 cigarettes a day spends on smoking:
      i. each day
      ii. each week
      iii. each year.



12. SI Study the graph provided, which shows that the number of deaths from lung cancer has risen as cigarette consumption has increased, but there is a 20-year lag time because lung cancer takes years to develop.



   a. **Describe** how the incidence of lung cancer deaths changed between 1900 and 1980.
   b. **Identify** when the number of male smokers peaked.
   c. **Identify** when the number of deaths from lung cancer peaked.
   d. **Explain** why there is a 20-year gap between the two numbers.
   e. The graph shows data for male smokers only. **Predict** when the number of cases of lung cancer deaths in women peaked (use the graph you drew for question 10 to answer this).

13. SI Think about the claims that vaping is safer than smoking cigarettes. Create a table that lists the reasons. Then consider what you know about the risks of e-cigarettes to teenagers and write your thoughts.

Answers and sample responses are available in your digital formats.

LESSON 3.10 Excretory system

LEARNING INTENTION

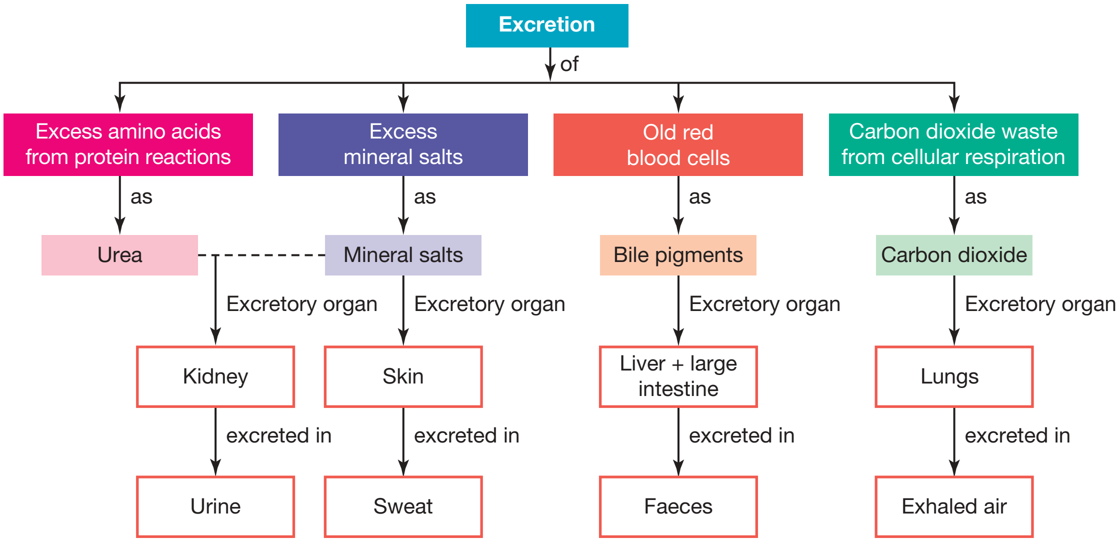
In this lesson you will describe the structure and function of the excretory system and provide examples of problems associated with it.

Being alive requires energy and nutrients. It also results in the production of wastes that need to be removed.

3.10.1 Excretion

Excretion is any process that gets rid of unwanted products or waste from the body. The main organs involved in human excretion are your **skin**, lungs, **liver** and **kidneys**. Your skin excretes salts and water as sweat, and your lungs excrete carbon dioxide (produced by cellular respiration) when you breathe out. Your liver is involved in breaking down toxins for excretion, and your kidneys are involved in excreting the unused waste products of chemical reactions (e.g. urea) and any other chemicals that may be in excess (including water) so that a balance within our blood is maintained.

FIGURE 3.77 The four main organs involved in human excretion are the kidneys, skin, liver and lungs.



3.10.2 Kidneys

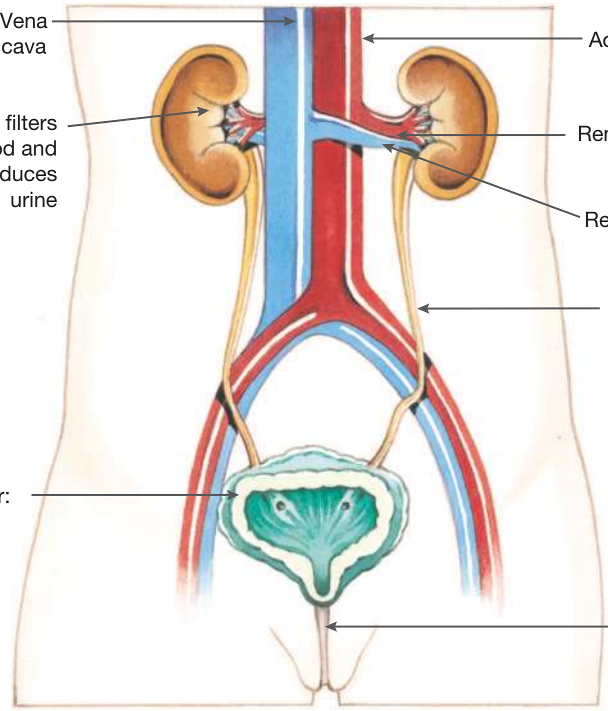
If you put your hands on your hips, your kidneys are close to where your thumbs are (figure 3.78). You have two of these reddish-brown, bean-shaped organs. Without them you would survive only a few days.

Organs, tubes and urine

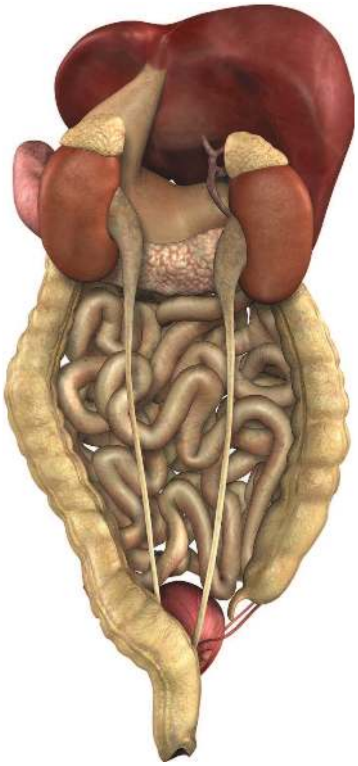
Your kidneys play a key role in filtering your blood and keeping the concentration of various chemicals and water within appropriate levels. Each of your kidneys is made up of about one million **nephrons**. These tiny structures filter your blood, removing waste products and chemicals that may be in excess. Chemicals that your body needs are reabsorbed into capillaries. The fluid remaining in your nephrons travels through tubes called **ureters** to your **bladder** for temporary storage. As it fills, your bladder expands like a balloon. It can hold about 400 mL of this watery fluid that contains unwanted substances, called **urine**. **Urination** occurs when urine moves from your bladder through a tube called the **urethra** and out of your body.

FIGURE 3.78 Your kidneys have an important role in the excretion of wastes from your body. **a.** A 2D image of the kidneys and bladder **b.** A rear 3D image of the location of the kidneys and bladder relative to organs in the digestive system

a.



b.

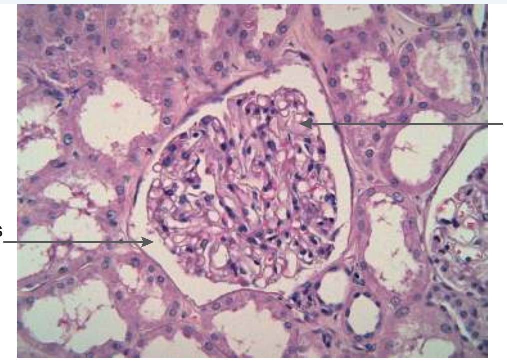


Nephrons — how their structure suits their function

Each nephron is made up of a long tubule (very fine tube) that forms a cup-like structure at one end called the **Bowman's capsule**. This structure surrounds a cluster of capillaries called the **glomerulus** (from an ancient Greek word meaning 'filter'), as seen in figure 3.79.

Blood containing wastes travels to the glomerulus within each nephron in your kidneys, where the blood is filtered. Wastes and excess water move into the surrounding Bowman's capsule. As this 'waste' fluid moves along the tubules, any useful substances are reabsorbed back into capillaries that are 'twisted' around the tubules, and hence back into circulation. The remaining fluid becomes urine, which eventually travels in your ureters to your bladder prior to urination.

FIGURE 3.79 In this kidney cell, you can see the Bowman's capsule and the glomerulus.



3.10.3 Have a drink!

Both blood and urine are mostly made up of water. Water is very important because it assists in the transportation of nutrients within and between the cells of the body. The concentration of substances in blood is also influenced by the amount of water in it.

Water helps the kidneys do their job because it dilutes toxic substances and absorbs waste products so that they can be transported out of the body. If you drink a lot of water, more will be absorbed from your large intestines, and your kidneys will produce a greater volume of dilute urine. If you do not consume enough liquid, you will urinate less and produce more concentrated urine.

FIGURE 3.80 How your kidneys work to remove waste from your body.

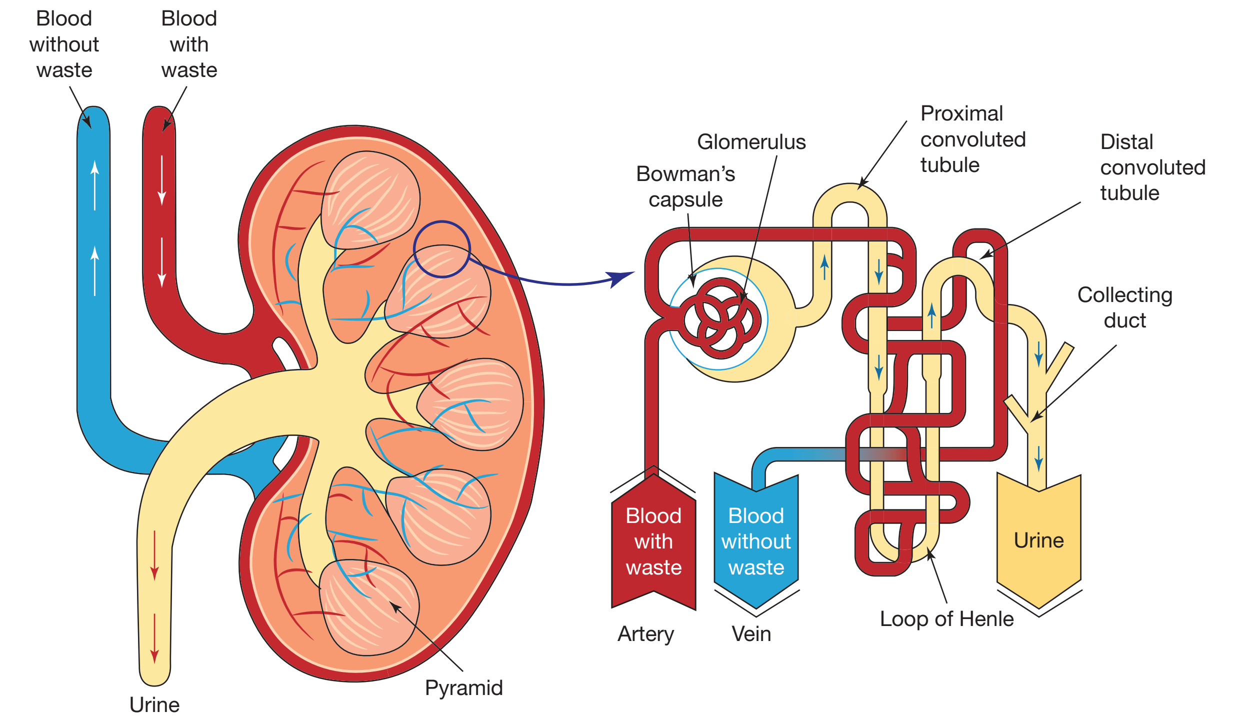
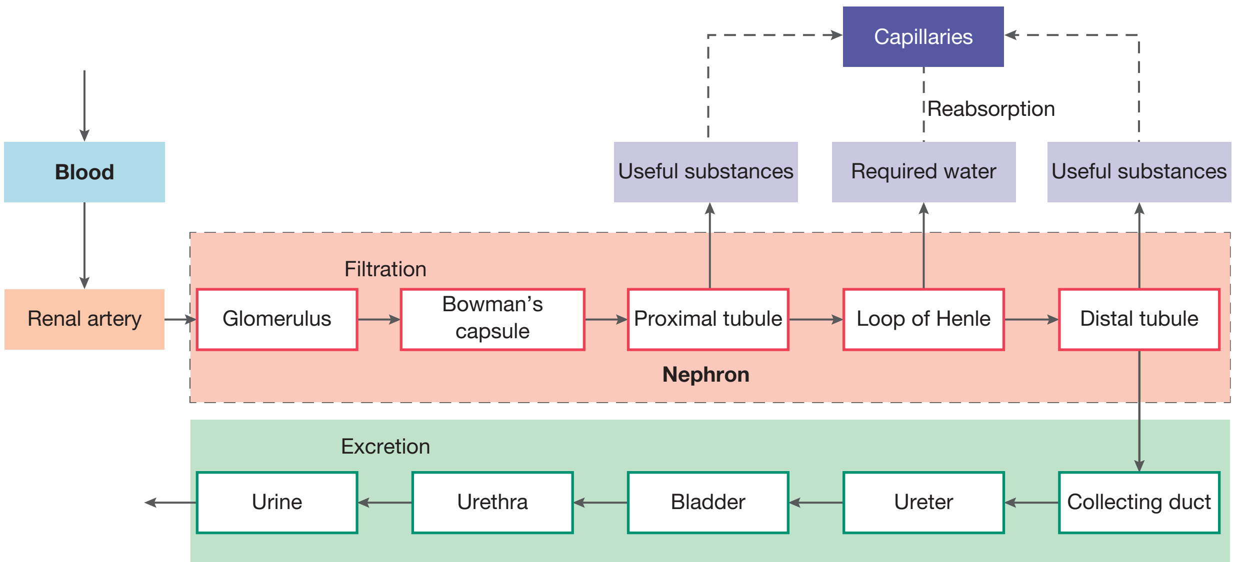


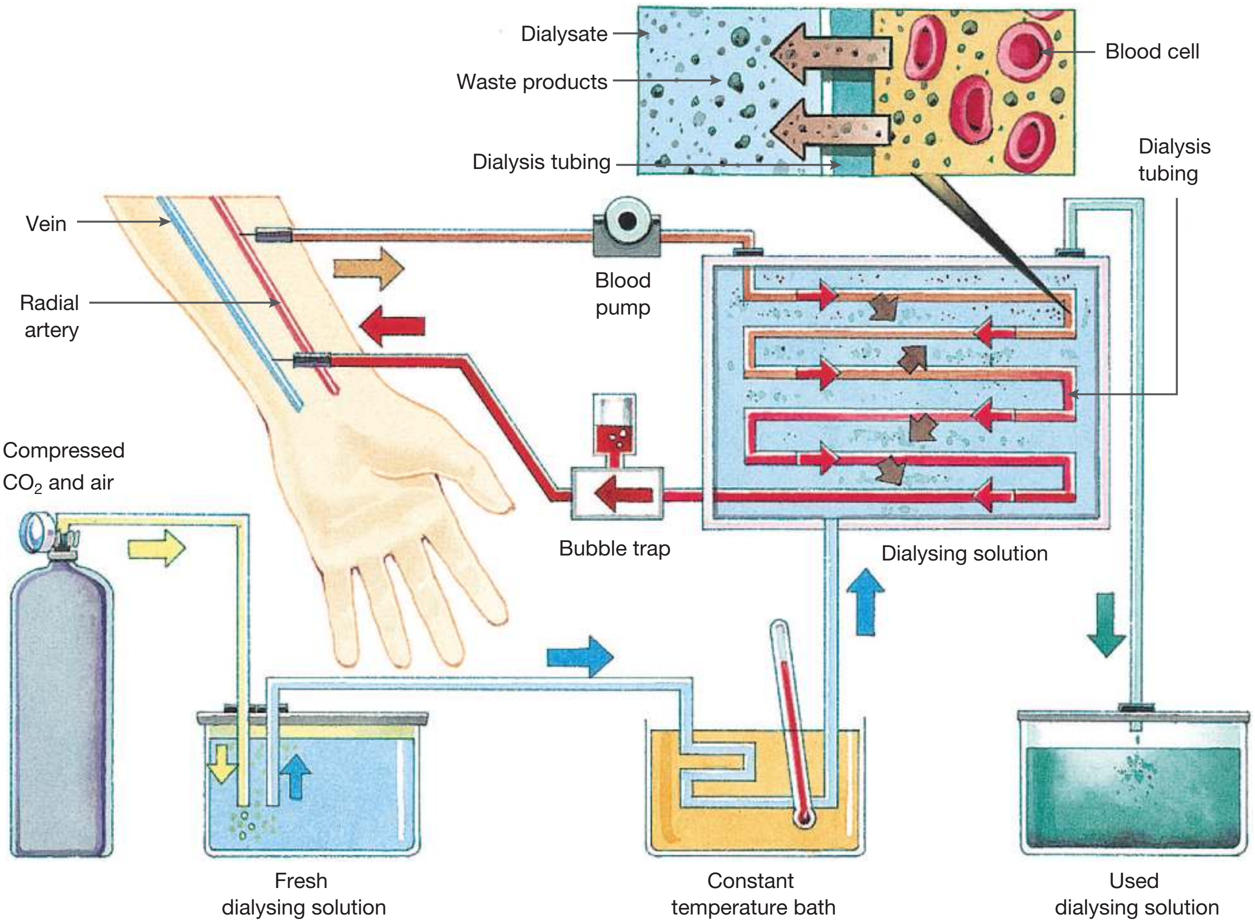
FIGURE 3.81 An organised approach is required for your excretory system to work effectively. Although each structure has its own specific job to do, it is also dependent on other structures doing their jobs as well.



3.10.4 Haemodialysis

People with kidney disease may not be able to remove the waste materials from their blood effectively. They may need to be linked up to a machine that does this job for them. Their blood is passed along a tube that lets wastes, such as urea, pass out of it. However, useful substances, such as glucose, proteins and red blood cells, stay in the tube and are kept in the blood. This process is called **haemodialysis** and is seen in figure 3.82.

FIGURE 3.82 Haemodialysis

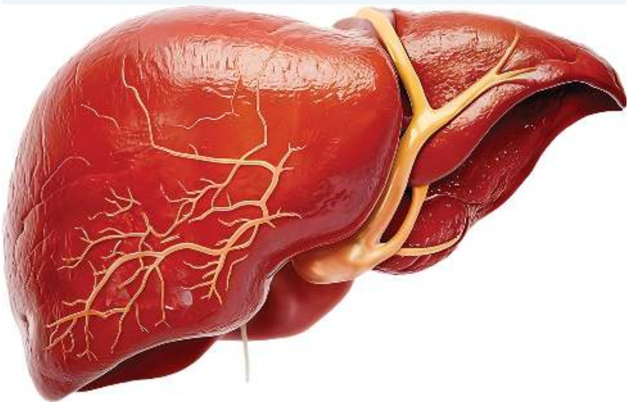


3.10.5 Liver

Livers are busy places!

Over a litre of blood passes through your liver each minute. Your liver is like a chemical factory, with more than 500 different functions. Some of these include sorting, storing and changing digested food. The liver removes fats and oils from the blood and modifies them before they are sent to the body's fat deposits for storage. It also helps get rid of excess protein, which can form toxic compounds dangerous to the body. The liver converts these waste products of protein reactions into urea, which travels in the blood to the kidneys for excretion. It also changes other dangerous or poisonous substances so that they are no longer harmful to the body. Your liver is an organ that you cannot live without.

FIGURE 3.83 The liver performs over 500 different functions.



Too much alcohol?

The liver is also involved in breaking down alcohol. Alcohol is converted into a substance called acetaldehyde, which is then converted to acetate and finally into carbon dioxide and water. The carbon dioxide is transported from the liver to the lungs and then exhaled out of the body. The water may be removed as vapour in breath, sweat on skin or as urine.

Alcohol can also affect the amount of urine produced by the kidneys. Reabsorption of water may be reduced in the kidneys, resulting in the production of more urine. Increased urination can result in dehydration and consequently impair other body functions.

EXTENSION: Removing excess salt

The human kidneys remove excess salt from the blood to help keep levels constant. Different types of animals have other ways of removing excess salt from their bodies. Turtles, for example, have salt-secreting glands behind their eyes. Hence, you may see a turtle 'shedding tears'. On the other hand, penguins and some other seabirds, such as the southern giant petrel, may appear to have runny noses because that is where their salt-secreting glands are located.

SCIENCE AS A HUMAN ENDEAVOUR: Organoids

Organoids are tiny, simplified versions of human organs that scientists grow in the lab. They are made from **stem cells**, which are special cells that can develop into different types of cells in the body. These organoids are designed to mimic the structure and function of real organs, but they are much smaller and less complex.

Scientists use organoids to:
- study how organs develop and function
- model diseases like cancer to understand how they affect the body
- test new drugs in a way that is more accurate than using animals
- potentially grow tissues or organs for transplants in the future.

For example, if scientists want to test a new cancer treatment, they can use an organoid grown from human stem cells to see how the treatment works without needing to test it on animals or people first.

Organoids have many benefits, such as the following.
- *Ethical improvements:* They reduce or replace the need for live animals in research.
- *Accuracy:* Because they are grown from human cells, they are better at showing how drugs will work in humans.
- *Efficiency:* They are cheaper and faster to produce than maintaining live animals.
- *Environmental impact:* Using organoids reduces the resources needed to care for and store live animals.

Organoids are becoming an important tool in medical research and may one day even help save lives through organ transplants.

1. Replacing live animals with organoids for medical testing is considered more ethical. Why do you think this is important, and how might this change public opinions about medical research?
2. Organoids are cheaper, faster and potentially more accurate than live animal testing. How could this advance the development of treatments for diseases such as cancer? What are some potential challenges in using organoids for research or transplants?

Proposed scientific responses to socio-scientific issues impact on society and may involve ethical, environmental, social and economic considerations (VC2S8H03)

3.10 Activities

learnon

3.10 Quick quiz on	3.10 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 5, 6, 7	2, 8, 9, 11, 13	3, 10, 12, 14

Remember and understand

1. a. **State** whether the following statements are true or false.

Statement	True or false?
i. Excretion involves getting rid of unwanted products or wastes from the body.	
ii. Skin, lungs, liver and kidneys are the main organs involved in human excretion.	
iii. Human skin is involved in the excretion of carbon dioxide.	
iv. Human lungs excrete urea.	
v. Human kidneys remove excess salt from the blood to help keep levels constant.	
vi. The liver converts waste products of protein into urea, which is then excreted via the kidney.	
vii. Blood and urine are mostly made up of water.	
viii. If you drink a lot of water, less will be absorbed from your large intestines and your kidneys, which will result in a greater volume of dilute urine.	
ix. The filtering of blood in each nephron of your kidney occurs in the glomerulus.	
x. Blood in your renal artery contains less 'waste' than blood in your renal vein.	

   b. Rewrite any false responses.

2. Match the terms associated with the excretory system with their description in the table shown.

Term	Description
a. Bladder	A. Watery fluid produced by kidneys that contains unwanted substances
b. Kidney	B. Transports urine from the bladder to outside the body
c. Ureter	C. Stores urine
d. Urethra	D. When urine moves from the bladder, through the urethra and out of the body
e. Urination	E. Transports urine from kidneys to bladder
f. Urine	F. Filters the blood and produces urine

3. **Define** the term *excretion*.

4. **Construct** a labelled diagram of the kidneys, showing the following attachments: renal arteries, renal veins, ureters, bladder.
5. **Outline** what happens when you drink a lot of water.
6. **Describe** one way in which excess salt is removed from your body.
7. **Explain** how haemodialysis assists people with kidney disease.
8. **Describe** the relationship between:
   a. a kidney and a nephron
   b. kidneys and urine
   c. alcohol, lungs and kidneys.

Apply and analyse

9. SI **a.** Carefully observe the haemodialysis diagram in figure 3.83. **Suggest** reasons the following are included in the process.
   a. i. Blood pump
      ii. Bubble trap
      iii. Constant temperature bath
   b. **Suggest** what you would expect to find in used dialysis solution.
   c. **Suggest** why red blood cells don't pass through the dialysis tubing.
   d. **Construct** a Venn diagram to compare haemodialysis with real kidneys.
10. **Distinguish** between:
   a. the ureter and the urethra
   b. a Bowman's capsule and a glomerulus
   c. the bladder and the kidney.
11. Report on:
   a. the differences between the urethra in human males and human females
   b. why pregnant women often need to urinate more frequently
   c. how the prostate gland in males may affect urination in later life
   d. which foods can change the colour or volume of urine
   e. which tests use urine in the medical diagnosis of diseases.

Evaluate and create

12. Think about the nephrons of animals that live in different environments such as deserts, oceans or rivers. What similarities and differences do you think their structures might have? Why do you think these differences exist?
13. SI Use the table provided and the other information in this lesson to answer the following questions.

Substance	Quantity (%)	
	In blood	In urine
Water	92	95
Proteins	7	0
Glucose	0.1	0
Chloride (salt)	0.37	0.6
Urea	0.03	2

   a. **Construct** two bar graphs to show the quantity of water, proteins, glucose, salt and urea in blood and in urine.
   b. Which substance is in the greatest quantity? **Suggest** a reason for this.
   c. Which substances are found only in blood?
   d. Which substances are found in urine in a greater quantity than in blood? **Suggest** a reason for this.
   e. When would the amount of these substances in the urine become greater or less than in the blood?
14. SI **Construct** a model of a nephron that shows how it is linked to blood vessels and how urine gets to your bladder from it.

Answers and sample responses are available in your digital formats.

LESSON 3.11 Same job, different path

LEARNING INTENTION

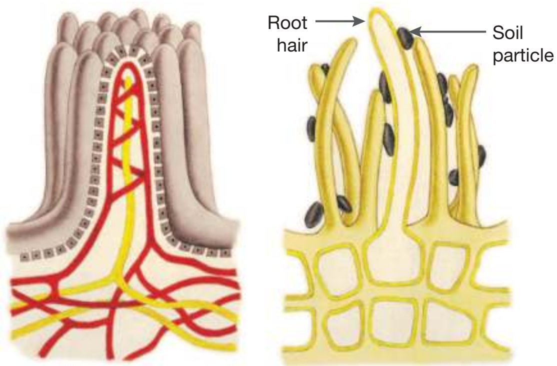
In this lesson you will provide examples of how variations in the structures of the organs in the respiratory and digestive systems make them well suited to perform their specific tasks.

3.11.1 Patterns, order and organisation

Similar, but different? While organisms can have different solutions to life's challenges, these differences share similar patterns, order and organisation.

Organisms possess a variety of structures that help them to obtain the resources they need to survive. While there are similarities and patterns in some of these structures, there are also differences. These differences provide examples of wonderful and creative solutions to the continual challenge of staying alive.

FIGURE 3.84 Similar structures? What might their function be?



Shaping clues

The structures of cells and tissues often provide clues to their function. For example, structures that are involved in absorption often have shapes that increase their surface area-to-volume ratio. Intestinal villi in humans and plant root hairs are examples of this. Can you see the similarities in figure 3.84? Can you think of other cells or tissues that also share this pattern?

3.11.2 Respiratory routes

Cellular respiration is essential for life. Organisms require a supply of oxygen and a way to remove the carbon dioxide that is produced as waste. This process is summarised by the equation:

glucose + oxygen → carbon dioxide + water + energy

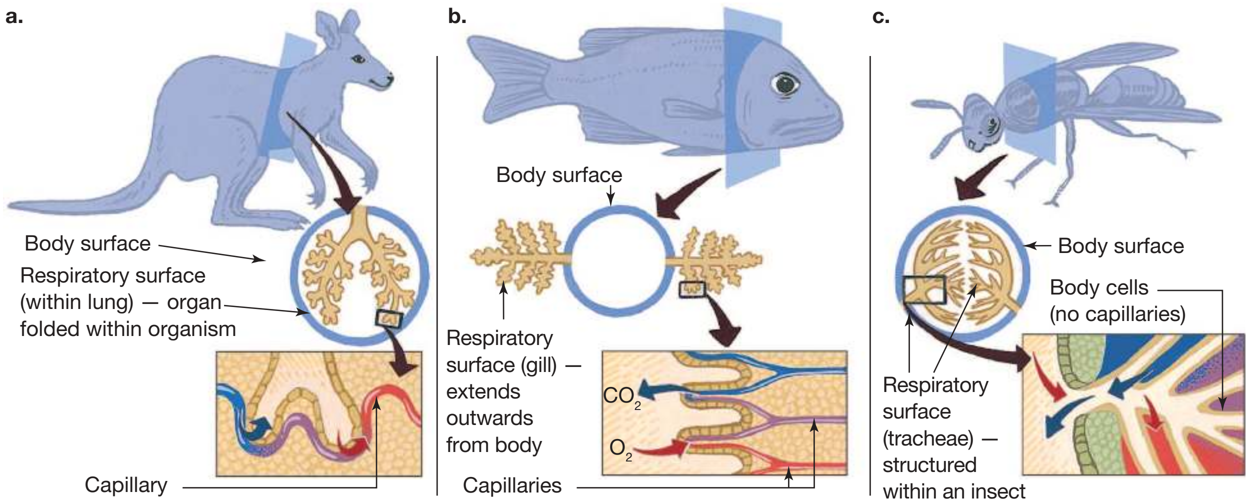
Although this gaseous exchange is essential, different types of organisms achieve it in different ways.

FIGURE 3.85 A flatworm

Unicellular organisms are small enough that gases such as oxygen and carbon dioxide can simply diffuse in and out of their cell. Likewise, some very thin multicellular organisms have many of their cells in direct contact with their environment. These organisms rely simply on diffusion for their exchange of gases. Flatworms (figure 3.85), for example, do not need a respiratory system, as they use their whole body surface to obtain the oxygen they require from the water in which they live. Some other small animals, such as worms living on land, can exchange gases through their mucus-covered skin. Oxygen from the air dissolves in the mucus, while carbon dioxide seeps out. Tiny blood vessels in their skin transport the gases to and from the rest of the worm's body.

Other animals may have specialised gas exchange organs. Three main kinds of these organs are lungs in mammals and amphibians, gills in fish and tracheae in insects. Examine figure 3.86 to compare the structure of these organs. How are they similar? How are they different?

FIGURE 3.86 Notice any similarities or differences in these gas exchange surfaces?



In topic 2 (section 2.7.1), it was seen that plants undergo a process called photosynthesis, where carbon dioxide from the air, water from the soil and energy from sunlight are converted to oxygen, and glucose in chloroplasts.

$$\text{carbon dioxide} + \text{water} + \text{energy} \rightarrow \text{oxygen} + \text{glucose}$$

This is how plants 'breathe'; however, production of oxygen can only occur during the day when there is sunlight. Plants then gain their energy from cellular respiration of the glucose produced.

3.11.3 Digestive differences

Although most vertebrates possess a digestive system that has a similar pattern, order and organisation, there may be differences that are related to nutritional needs and diet. Consider, for example, differences in the digestive systems of **herbivores** with diets that are high in plant material with lots of cellulose, compared with those of carnivores with lots of animal flesh, which are high in protein (figure 3.87). How would these compare with the digestive system of an organism that ate only nectar and pollen?

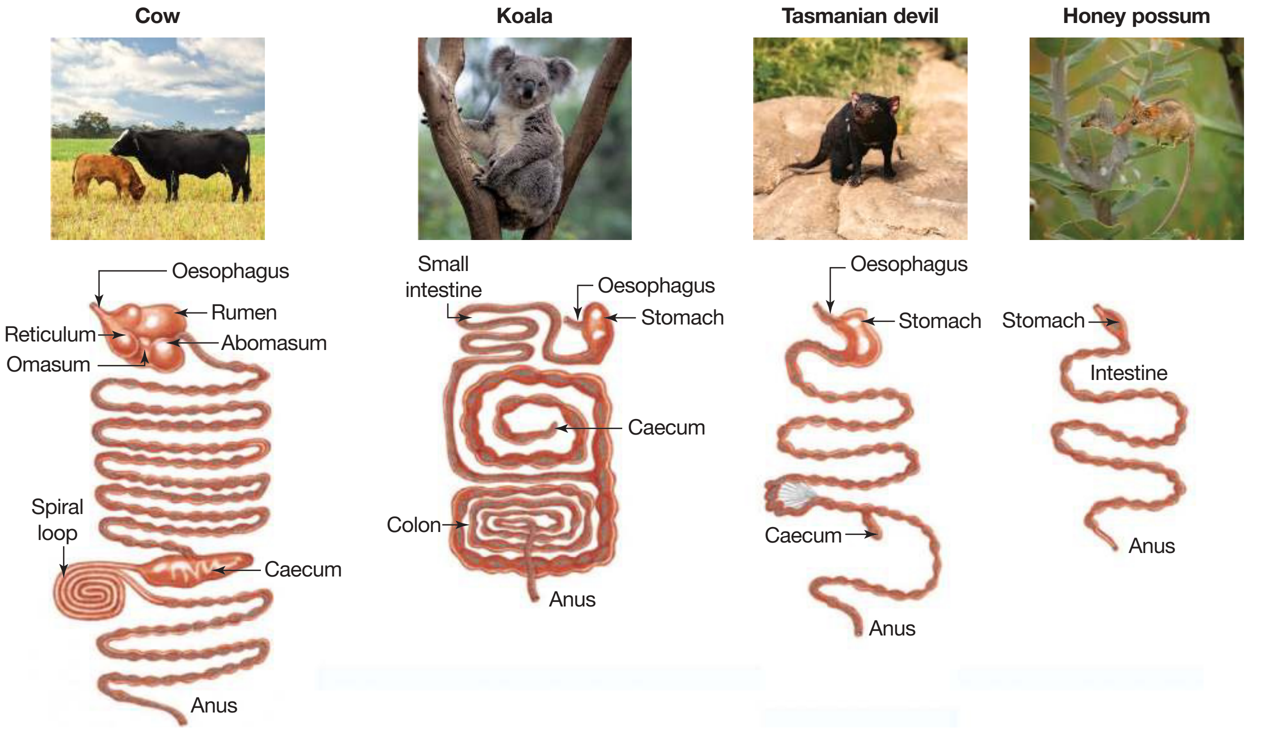
DISCUSSION

Some animals that live in water, such as sea anemones, have a digestive sac that acts as both a mouth and an anus. Find out more about the digestive system of sea anemones.

a. Describe how this digestive system is similar to that of humans and how it is different.
b. Suggest reasons for the differences.

As the process of photosynthesis also creates the food that most plants need, they do not have a specific digestive system. However, there are some plants, like *Dionaea muscipula* (Venus flytrap, figure 3.88), that also catch prey for essential nutrients, including nitrogen and phosphorus. Once the trap closes, the digestive glands release enzymes to break down the prey. In this instance, the mouth is also the stomach. Once the enzymes have done their job, the nutrients are absorbed into the leaf to be used. After a few days, the trap will re-open, leaving behind the **exoskeleton** of the prey.

FIGURE 3.87 Notice any similarities or differences in these digestive systems?



Cow	Koala	Tasmanian devil	Honey possum
HERBIVORE (foregut fermenter) Four-chambered stomach with large rumen; small and large intestines are long	HERBIVORE (hindgut fermenter) Small stomach; large caecum	CARNIVORE Intestine and colon both short; small caecum	NECTAR AND POLLEN EATER Digestion of nectar generally not required; very short intestine for digestion of pollen

FIGURE 3.88 An unlucky fly being eaten by a Venus flytrap

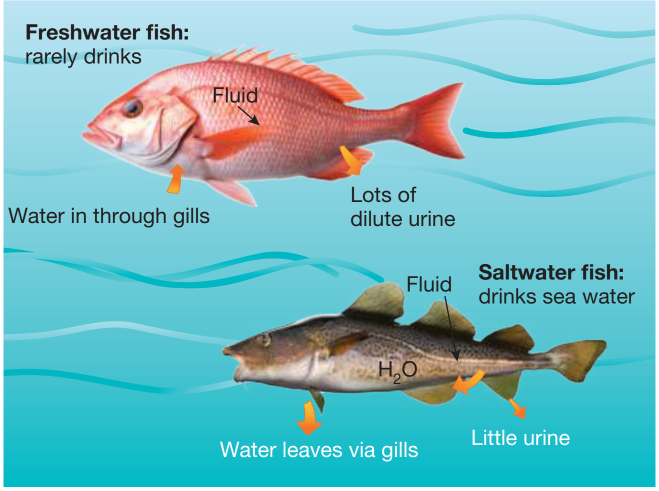
3.11.4 Throwing out the trash!

Different types of fish, living in different environments, can also differ in how they maintain their salt balance.

Proteins are involved in a variety of chemical reactions that keep animals alive. **Ammonia** is formed when proteins break down. Ammonia is toxic to cells and requires either dilution with lots of water, or conversion into a less toxic form (such as urea or uric acid). Conversion into other forms costs the animal energy. Whichever form these **nitrogenous wastes** are in, they need to be removed from the animal's body.

Different types of animals use different strategies to remove nitrogenous wastes. This is linked to the amount of water available in the environments in which they live. Fish, for example, have a ready supply of water, so most fish release their nitrogenous waste as ammonia (figure 3.89). The main nitrogenous waste excreted by humans is **urea**.

FIGURE 3.89 Saltwater fish, such as snapper, drink seawater constantly and produce a small volume of urine. However, freshwater fish, such as Murray cod, rarely drink, but make lots of urine.



Uric acid requires the least water for excretion. Insects, spiders and birds excrete their wastes as uric acid. The uric acid produced by birds is solid; it is stored in their bodies without diluting it with water and is excreted with their faeces (figure 3.90). Animals living in dry environments, such as insects and snakes, also excrete their wastes in this form to conserve water.

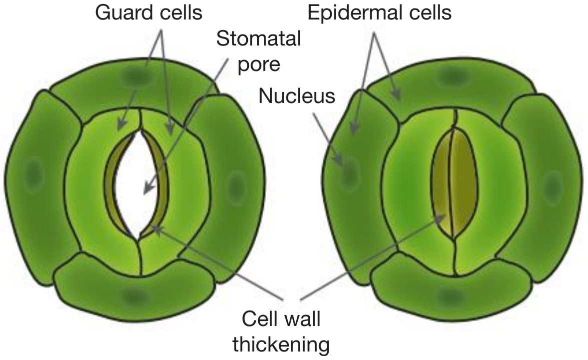
FIGURE 3.90 Birds produce nitrogenous waste in a form of solid uric acid. What advantage do they gain from this?

Have you noticed the pattern? The environment in which an organism lives, in this case the amount of water available, can play a role in how different species have evolved different strategies to the same problem of removal of their wastes.

In plants, the waste products are removed in a variety of ways. Water vapour and gaseous wastes, including carbon dioxide, are released through the stomata (topic 2, section 2.8.3). Some of the waste is also stored in the vacuole of the leaf cell, which then eventually falls off the plant.

FIGURE 3.91 a. The stomata are important for allowing waste products to be removed from the plant.
b. Stomata can be found on both the top and underside of a leaf.

a.



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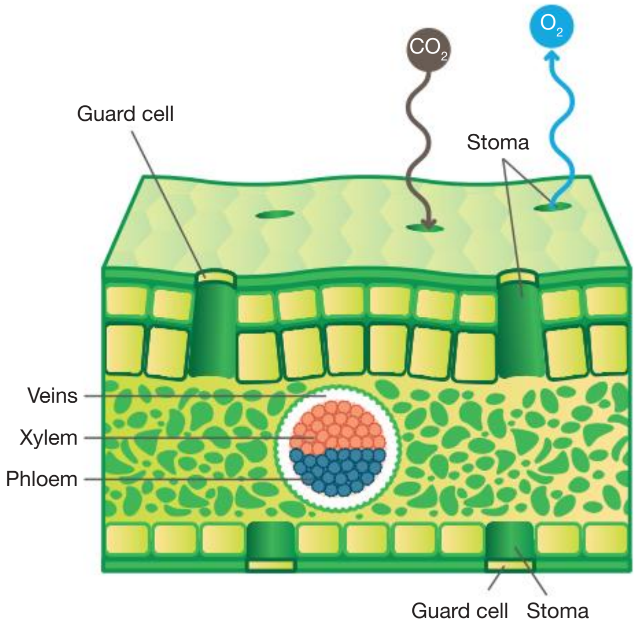

3.11 Activities

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3.11 Quick quiz	3.11 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 4, 6, 12	3, 7, 10	5, 8, 9, 11, 13

Remember and understand

1. a. **State** whether the following statements are true or false.

Statement	True or false?
i. The structures of cells and tissues often provide clues to their function.	
ii. Structures involved in absorption often have shapes that increase their surface area-to-volume ratio.	
iii. Unicellular organisms are small enough that gases such as oxygen and carbon dioxide can simply diffuse in and out of their cell.	
iv. Respiratory surfaces in different animals can have shapes that make them efficient at exchanging gases such as oxygen and carbon dioxide.	
v. Intestinal villi in humans and root hairs in plants have shapes that reduce the surface area-to-volume ratio available for exchange of materials.	
vi. Humans excrete their nitrogenous wastes as uric acid, whereas birds excrete it as urea.	

(continued)

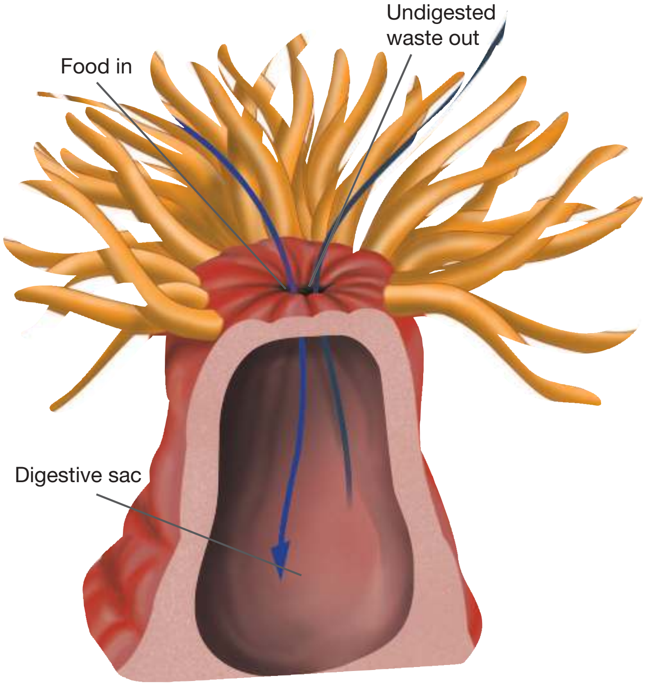
Statement	True or false?
vii. Freshwater fish rarely drink and produce little urine, whereas saltwater fish constantly drink and produce lots of urine.	
viii. Ammonia, formed when proteins break down, is toxic to cells.	
ix. The strategies that different types of animals use to remove nitrogenous wastes is not influenced by the amount of water available in the environments in which they live.	

b. Rewrite any false responses.

2. Place the following terms in order of simplest to most complex: cell, organ, system, multicellular organism, tissue.
3. Provide an example of how structure can give clues about function.
4. Write the word equation for cellular respiration.
5. **Describe** two key functions of gaseous exchange.

Apply and analyse

6. **Name** two organs belonging to each of the following systems.
   a. Respiratory system
   b. Circulatory system
   c. Excretory system
7. **Suggest** why there are differences between herbivores and carnivores in the structures of their digestive systems.
8. a. **Outline** the key differences between the structures of the digestive systems of a cow, a koala, a Tasmanian devil and a honey possum.
   b. **Suggest** reasons for the differences.
9. Some animals that live in water, such as sea anemones (shown in the figure), have a digestive sac that acts as both a mouth and an anus.



   a. **Construct** a model to demonstrate your understanding of how it works.
   b. **Describe** how this digestive system is similar to that of humans and how it is different.
   c. **Suggest** reasons for the differences.
10. **Compare** the structure of the small intestine with the lungs. How does each organ's structure help it carry out its specific function? **Explain** using examples.

Evaluate and create

11. SI Formulate scientific questions about how the structure of the heart, kidney or lungs is related to the function of that organ. Write a report that answers one of the questions.
12. SI Design and **construct** a model of one of the following systems: respiratory, excretory, reproductive, digestive.
13. **Evaluate** how the shape and structure of the lungs help in the exchange of gases. Design a new feature for the lungs that could make the gas exchange process even more efficient. **Describe** how your feature would work.

Answers and sample responses are available in your digital formats.

LESSON 3.12 Review

3.12 Success criteria

Tick the column to indicate that you have completed the lesson and how well you think you have understood it using the traffic light system.

(**Green:** I understand; **Yellow:** I can do it with help; **Red:** I do not understand)

Lesson	Success criteria	Green	Yellow	Red
3.2	I can understand that scientific knowledge and understanding of the world changes as new evidence becomes available.			
	I can provide examples of how our knowledge and understanding of the human body has changed over time.			
3.3	I can provide examples of how the different body systems — made up of specialised organs, tissues and cells — work together to keep multicellular organisms alive.			
3.4	I can describe the structure and function of the digestive system.			
3.5	I can give examples of ways in which science and technology have contributed to scientific knowledge and understanding of the digestive system, and have led to related improved medical treatments.			
3.6	I can describe the structure and function of the circulatory system.			
3.7	I can provide examples of how, due to discoveries made using new and improved technologies, our understanding of the circulatory system has changed over time.			
3.8	I can describe the structure and function of the respiratory system.			
3.9	I can describe examples of illnesses and problems associated with the respiratory system.			
3.10	I can describe the structure and function of the excretory system and provide examples of problems associated with it.			
3.11	I can provide examples of how variations in the structures of the organs in the respiratory and digestive systems make them well suited to perform their specific tasks.			

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Post-test	Topic 3 Post-test
eWorkbook	Topic 3 eWorkbook
Digital document	Key terms glossary

3.12 Activities

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3.12 Review questions

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 4, 5, 6, 7, 22, 23	8, 10, 11, 12, 14, 15, 18, 19, 20	9, 13, 16, 17, 21

Remember and understand

1. a. **Identify** whether the following statements are true or false.

Statement	True or false?
i. Multicellular organisms are made up of different types of cells that cannot survive independently of each other so they need to work together.	
ii. The cells that make up multicellular organisms are all the same.	
iii. The shape and size of different types of cells within a multicellular organism, and differences in structures within them, make them well suited to their specific function.	
iv. Tissues are structures within cells that have a particular job to do.	
v. Organelles are a collection of similar cells that perform a particular function.	
vi. Organs are made up of different types of tissues grouped together to perform a particular function.	
vii. Systems are made up of different organs working together to perform a specialised function to keep an organism alive.	
viii. The excretory system supplies your body with the nutrients it requires to function effectively.	
ix. The stomach, liver, gall bladder, intestines and pancreas are all organs of the respiratory system.	
x. When you burp, some of your stomach acid can rise into your oesophagus and cause heartburn.	

   b. Rewrite any false responses.
2. Order the following from most complex to least complex: cells, systems, multicellular organisms, tissues, organs.
3. **Identify** which description matches the term in the table shown.

Term	Description
a. Tissue	A. A collection of similar cells that perform a specific function
b. Organ	B. Different organs working together to perform a specialised function to keep an organism alive
c. System	C. Different types of tissues grouped together to perform a specific function
d. Organelle	D. Structures within cells that have a specific function

4. Match the type of tissue with its function in the table shown.

Tissue	Function
a. Blood tissue	A. To bind and connect tissues together
b. Connective tissue	B. To bring about movement
c. Epithelial tissue	C. To carry oxygen and food substances around the body
d. Muscle tissue	D. To conduct and coordinate messages
e. Nerve tissue	E. To line tubes and spaces, and form the skin
f. Skeletal tissue	F. To support and protect the body, and permit movement

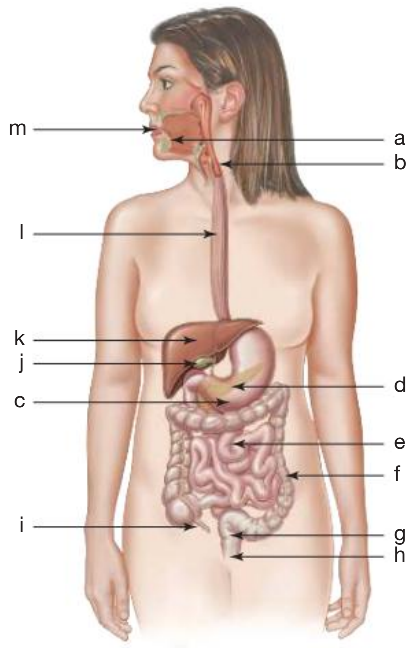
5. Match the organs with their system in the table shown.

Tissue	System
a. Brain, spinal cord	A. Circulatory system
b. Heart, blood vessels	B. Digestive system
c. Liver, kidneys, skin, lungs	C. Excretory system
d. Lungs, trachea	D. Nervous system
e. Stomach, liver, gall bladder, intestines, pancreas	E. Reproductive system
f. Testes, ovaries	F. Respiratory system

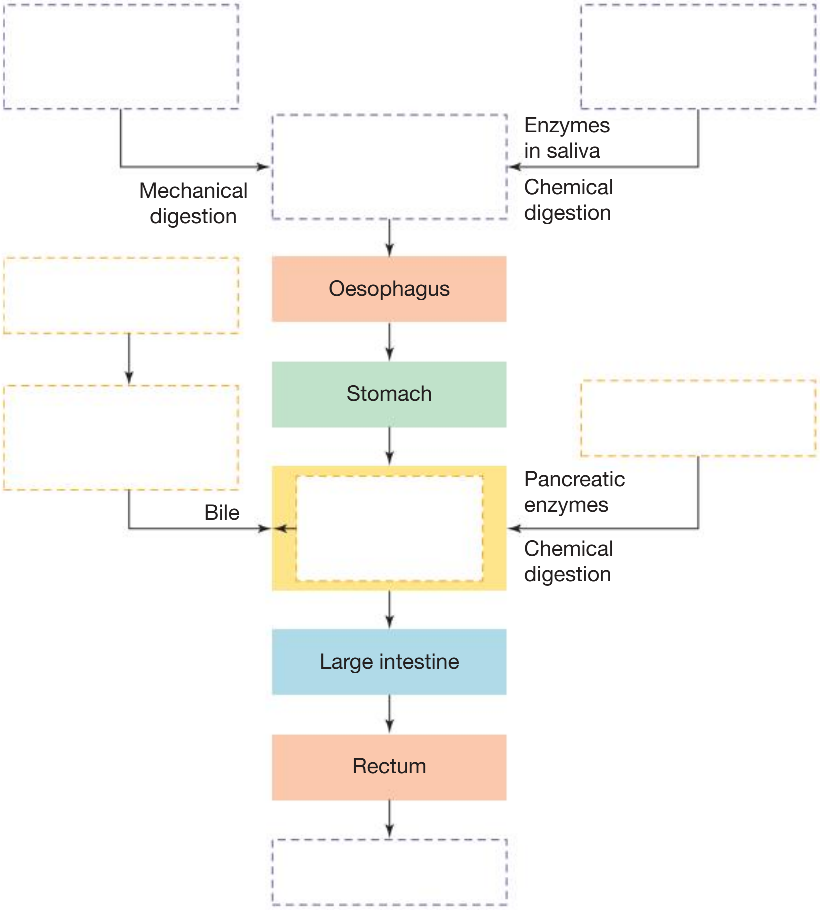
6. Match the system with its function in the table shown.

System	Function
a. Circulatory system	A. Removes waste products from your body
b. Digestive system	B. Supplies your body with nutrients it requires to function effectively
c. Excretory system	C. Takes oxygen in and removes carbon dioxide from your body
d. Respiratory system	D. Transports oxygen and nutrients to your body cells and transports wastes such as carbon dioxide from them

7. Label (a–m) this diagram of the human digestive tract.



8. Match the labels to the digestive system flowchart figure provided: anus, gall bladder, liver, mouth, pancreas, salivary glands, small intestine, teeth.



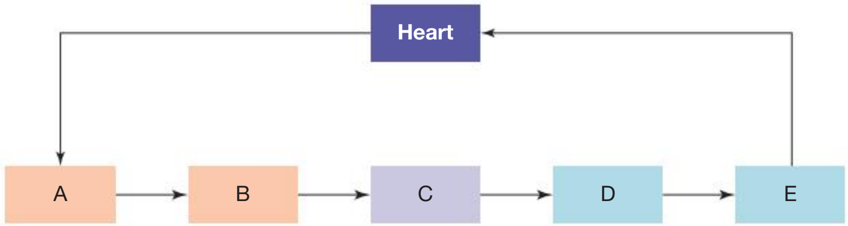
9. Match the process to the description in the table shown.

Process	Description
a. Absorption of nutrients	A. Physically breaking down food into smaller pieces
b. Assimilation	B. Occurs through villi in the small intestine into capillaries
c. Chemical digestion	C. Taking food into your body
d. Egestion	D. Use of chemicals called enzymes to break down food into small molecules
e. Ingestion	E. Undigested materials and wastes are removed from the body
f. Mechanical digestion	F. Conversion of broken-down food into chemicals in your cells

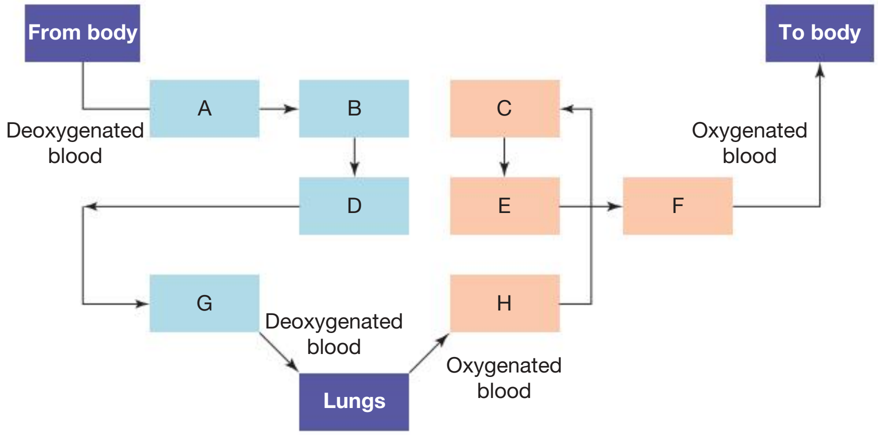
10. Match the organ to its function in the table shown.

Organ	Function
A. Small intestine	a. Makes bile, stores glycogen and breaks down toxins
B. Gall bladder	b. Makes enzymes used in the small intestine
C. Large intestine	c. Stores bile made in the liver until needed by the small intestine
D. Pancreas	d. Stores faeces
E. Stomach	e. Stores undigested food and waste while bacteria make some vitamins
F. Liver	f. Temporary storage of food and where protein digestion begins
G. Rectum	g. Tube that takes food from mouth to stomach
H. Oesophagus	h. Where the breakdown of starch and protein is finished and fat breakdown occurs

11. Match the labels to their position in the flowchart provided: artery, body cells, artery capillary, vein capillary, vein.



12. Label the figure provided.



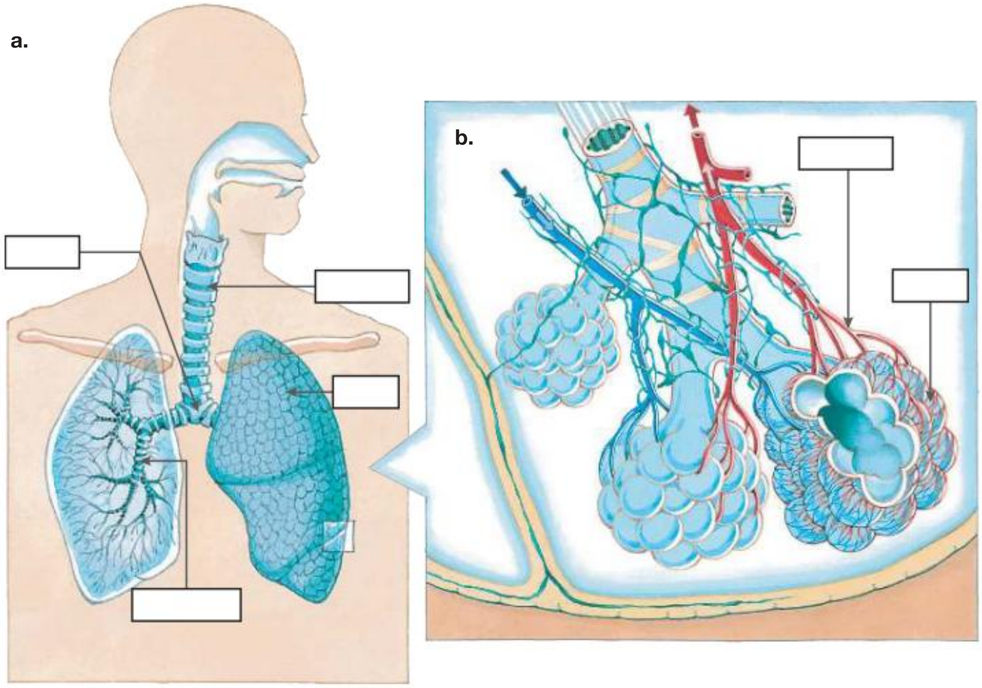
13. Match the term with its most appropriate description in the table shown.

Term	Description
a. Artery	**A.** Cells involved in transporting oxygen throughout the body
b. Atria	**B.** The bottom two chambers of the heart
c. Capillary	**C.** The top two chambers of the heart
d. Heart	**D.** Blood vessel that exchanges substances with cells
e. Red blood cells	**E.** Cells involved in production against infection
f. Vein	**F.** Organ that pumps blood around the body
g. Ventricles	**G.** Blood vessel that takes blood to the heart
h. White blood cells	**H.** Blood vessel that takes blood away from the heart

14. Match each term with the description of its function in the table shown.

Term	Description
a. Kidney	A. Transports urine from kidneys to bladder
b. Bladder	B. When urine moves from the bladder, through the urethra and out of the body
c. Urethra	C. Filters the blood and produces urine
d. Ureter	D. Stores urine
e. Urine	E. Transports urine from bladder to outside body
f. Urination	F. Watery fluid produced by kidneys that contains unwanted substances

15. **Suggest** labels for the diagrams shown.

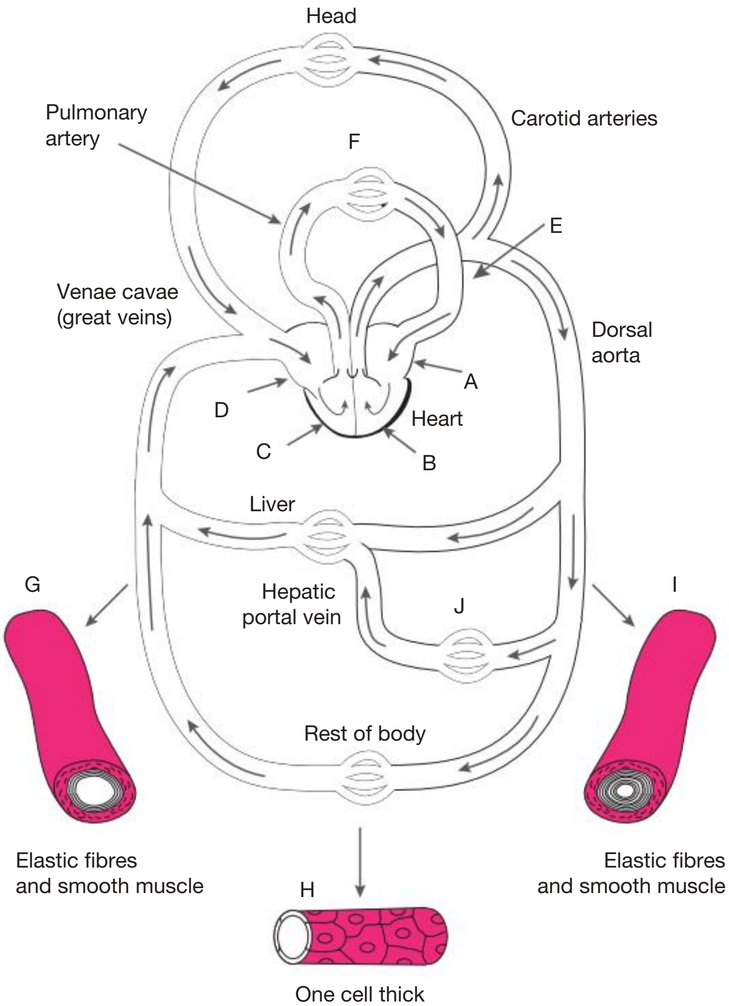


Apply and analyse

16. **Construct** a flowchart to show the correct sequence for the following parts of the digestive system: anus, mouth, oesophagus, stomach, small intestine, large intestine.
17. **Explain** how the structure of each of the following makes them well suited to their function.
    a. Red blood cells
    b. Human intestinal villi
    c. Arteries
    d. Capillaries
    e. Alveoli
    f. Molar teeth

18. Draw a copy of the diagram.

The human circulatory system

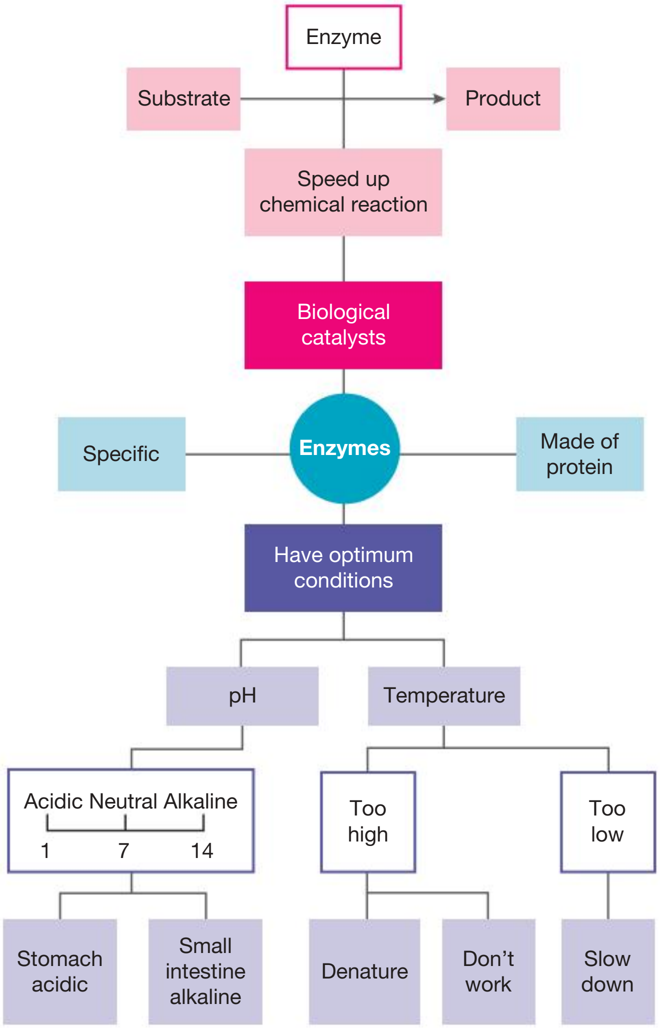


a. Label the lettered parts (A–J) of the human circulatory system and blood vessels on your diagram.
b. Use a red pencil to colour in the blood vessels with oxygenated blood, and a blue pencil for those with deoxygenated blood.
c. **State** whether the blood in the following blood vessels is deoxygenated or oxygenated.
- **i.** Aorta
- **ii.** Pulmonary artery
- **iii.** Pulmonary vein
- **iv.** Vena cava
- **v.** Carotid arteries

d. Draw a table that shows the differences in structure and function of the arteries, veins and capillaries.

Evaluate and create

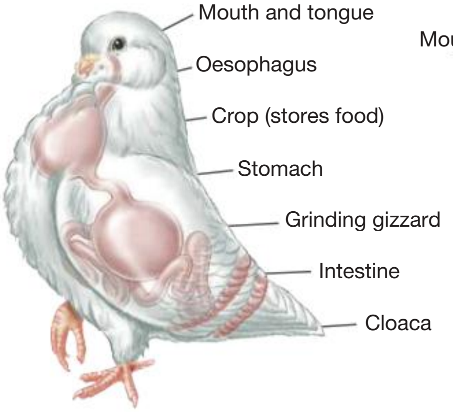
19. Carefully **examine** the diagram shown. What other points about enzymes could you add to this map? Can you **suggest** any more links between points already on the map?

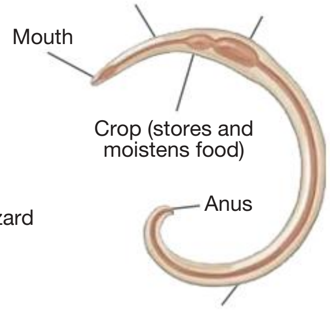


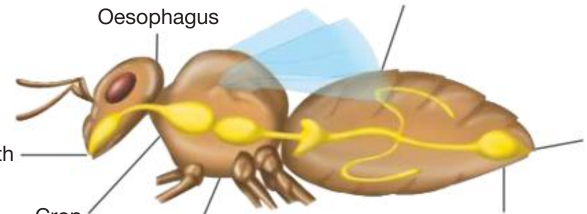
20. **Construct** Venn diagrams to compare the following.

a. Incisor teeth and canine teeth
b. Intestinal villi and alveoli
c. Red blood cells and white blood cells
d. Trachea and oesophagus
e. Mechanical digestion and chemical digestion

21. Carefully observe the diagrams of the digestive systems of the animals shown. **Construct** a matrix table that shows the similarities and differences between birds, earthworms, insects and humans.







22. Answer the following six questions for three of the issues or statements provided below (a. through i.)
   - What are the facts?
   - What thinking is needed?
   - What is wrong with this?
   - What new ideas are possible?
   - What are the good points?
   - What do I feel about this?

   a. Drinking of any alcohol in Australia should be illegal.
   b. Smoking in public should be punishable by a 10-year prison sentence.
   c. Donating blood at least four times a year should be compulsory for all over the age of 16.
   d. Only people under the age of 40 should be allowed to have a heart transplant.
   e. Smokers should not be allowed to have surgery.
   f. Blood transfusions should be illegal.
   g. Everyone should have the right to a blood transfusion.
   h. Organ donation should be compulsory.
   i. Overweight people should not be allowed to have surgery on their circulatory system.
23. Write a story that tells of the life of a red blood cell.

Answers and sample responses are available in your digital formats.

on To test your understanding and knowledge of this topic, go to your learnON title at www.jacplus.com.au and complete the **post-test**.

4 Elements, compounds and mixtures

CONTENT DESCRIPTION

The atomic theory of matter can be used to model and explain the difference between elements, compounds and mixtures; elements, compounds and mixtures can be represented as two-dimensional and three-dimensional models, elements can be represented by symbols, and molecules and compounds can be represented by chemical formulas (VC2S8U07)

Source: Victorian Curriculum F–10 Version 2.0

LESSON SEQUENCE

LESSON 4.1 Overview

4.1.1 Introduction

It is incredible to realise that everything that you see around you is made of very, very tiny particles called **atoms**, and it is even more amazing to find out that these atoms are made of even smaller particles and a lot of empty space. A substance made from only one type of atom is known as an element. Everything in the universe can be made up from about 90 naturally occurring **elements**. Some elements will be familiar to you:

- helium in balloons
- the oxygen that we breathe
- silver in jewellery
- iron in buildings.

All the atoms in a helium balloon are the same because helium is an element. Elements have their own atomic symbols. For example:

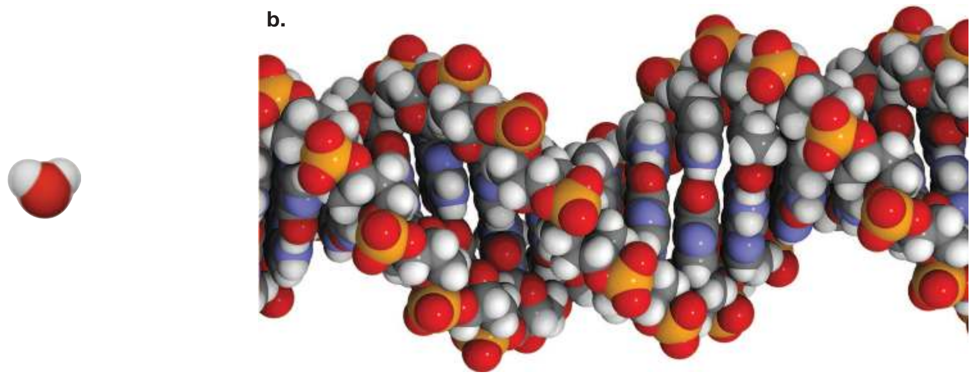
- **hydrogen**, the first element and a gas, has the atomic symbol H
- helium, also a gas, has the atomic symbol He
- silver, a metallic element, has the symbol Ag.

When different elements react together, they can form a **compound**. The properties of a compound are different from the elements that have reacted to make it. There are millions of different compounds, but one we use every day is water. Water is a compound because it is made up of two hydrogen atoms for every one oxygen atom. Hydrogen and **oxygen** are both non-metallic elements, which makes water a molecule. It is given the chemical formula H_2O. The **chemical formula** includes the atomic symbols for the elements present in the compound and indicates how many atoms of each are used to make it.

Molecules come in all sizes. A water molecule has only three atoms in each molecule, whereas a DNA (deoxyribonucleic acid) molecule has millions of atoms in each molecule (see figure 4.1). DNA that is found in our cells has the instructions that determine an individual's characteristics, such as hair and eye colour.

FIGURE 4.1 a. A water molecule has three atoms. **b.** A DNA (deoxyribonucleic acid) molecule has millions of atoms.

a. b.



The final group of substances that will be studied in this topic is the most common one. Most of the substances that we see around us are **mixtures**. The air that we breathe is a mixture of the gaseous elements nitrogen, oxygen, a very small amount of argon and a small amount of the compound carbon dioxide; there are minute quantities of other substances as well. Mixtures are substances that are not chemically combined, and the substances retain their own properties. Unlike compounds, the parts of a mixture are not necessarily in fixed proportions; for example, mixing sand, iron nails and sugar.

DISCUSSION

1. How did plumbers get their name?
2. Which metal can drive you crazy?
3. Can water be split?
4. Can you breathe nitrogen gas?
5. What is most of an atom made up of?
6. What is 'plastic' made from?
7. Which precious gem is made from the same substance as charcoal and soot?
8. Is milk a mixture?

SCIENCE INQUIRY: Investigating atoms

Atoms are tiny — so tiny that they are hard to visualise. But they can bring up some very big questions. Consider these questions and carry out investigation 4.1 to help you understand just how small, and how important, atoms really are.

1. Everything around you and in you is made of atoms, but what is an atom?
2. Who was the first person to say that everything is made of atoms?
3. Can we see individual atoms?
4. If matter is made of atoms, what are atoms made of?
5. How do we know what an atom looks like?
6. How many different types of atoms are there?
7. Are atoms of the same element the same?
8. What are the main types of atoms that are in us?
9. How small are atoms? How many hydrogen atoms do you think would fit on a pin head?

Investigable questions, reasoned predictions and hypotheses can be developed in guiding investigations to identify patterns, test relationships and analyse and evaluate scientific models (VC2S8I01)

INVESTIGATION 4.1

How big is an atom?

Aim

To investigate division of matter

Materials

- a strip of paper cut from A4 paper (about 30 cm long)
- pair of scissors
- ruler

Method

1. Construct a table like the one in the results section of this investigation, and record the length of the strip of paper.
2. Cut the strip of paper in half. Put one half aside. Measure the length of the other half.
3. Cut the measured half in half again. Again, put one half aside, and measure and record the length of the other half.
4. Before you go any further, predict how many times you will be able to cut the strip in half.
5. Continue this process until you can no longer cut the strip in half.

Cut the measured half in half again.

Results

Number of cuts	Length of strip (approximate)
0	30 cm
1	15 cm
2	7.5 cm (easy?)
3	
4	
5	
6	
7	
8	1 mm (you're doing well to get this far!)
9	
10	
12	Average width of human hair
14	
18	1 micron (1 millionth of a metre, one thousandth of a millimetre)
22	
26	
31	The size of a single atom

Note: Scale change after 10 cuts

Discussion

1. Determine how many cuts you were able to make. Was this number greater or less than your initial prediction?
2. Estimate the number of additional cuts required before the strip becomes too small to see.

Conclusion

Write a conclusion for your investigation into the division of matter by completing the sentence: "The smallest piece of paper that could be cut was...". Then describe your findings, explain what this shows about how matter can be divided, and analyse any patterns or observations from the investigation.

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Pre-test	Topic 4 Pre-test
eWorkbooks	Topic 4 eWorkbook Student learning matrix
Practical investigation eLogbook	Topic 4 Practical investigation eLogbook
Digital document	Key terms glossary

LESSON 4.2 It's elementary

LEARNING INTENTION

In this lesson you will:
- recognise how the work of scientists today compares with the work of the early alchemists
- describe the properties of some elements.

4.2.1 Discovering elements

SCIENCE AS A HUMAN ENDEAVOUR: The alchemists

About 1000 years ago, when kings and queens lived in castles and were defended by knights in shining armour, there lived the **alchemists**.

They chanted secret spells while they mixed magic potions in their flasks and melted metals in their furnaces. They tried to change ordinary metals into gold. They also tried to find a potion that would make humans live forever. They studied the movements of the stars and claimed to be able to see into the future. Kings and queens took the advice of the alchemists very seriously.

FIGURE 4.2 Alchemists believed that the four basic elements in nature were air, fire, water and earth.

The alchemists never found the secrets they were looking for, but they did discover many things about substances around us. During the same period, people who worked with materials also helped us to understand many everyday substances. Blacksmiths worked with metals to make stronger and lighter swords and armour, fabric dyers learned how to colour cloth, and potters decorated their work with glazes from the earth. Without the knowledge passed down by these people, the world as we know it would be very different!

Twelve important substances were discovered during these ancient times: **gold, iron, silver, sulfur, carbon, lead, mercury, tin, arsenic, bismuth, antimony** and **copper**. Alchemists discovered five of these.

1. How did the discoveries made by alchemists and craftspeople contribute to the development of modern chemistry, even though they were not using scientific methods?
2. What does the evolution of alchemy into chemistry tell us about how scientific knowledge changes as new evidence and better tools become available?
3. Why is it important to study the contributions of ancient knowledge, such as the discoveries of alchemists and blacksmiths, when learning about modern science?

Scientific knowledge, including models and theories, can change because of new evidence (VC2S8H01)

EXTENSION ACTIVITY: Medieval swords

Explore how swords were made in the middle ages.

Real science

In about the seventeenth century, people stopped thinking about magic and instead carried out **investigations** based on careful **observations**. These new seekers of knowledge were called **scientists**. They found that the 12 substances discovered during ancient times could not be broken down into other substances. Scientists investigated many common everyday substances as well, including salt, air, rocks, water and even urine!

FIGURE 4.3 Seventeenth-century scientists carried out investigations based on careful observations.

KEY IDEA

Scientists use investigations based on observations to make discoveries.

Scientists discovered that nearly everything around us could be broken down into other substances. They gave the name 'element' to the substances that could not be broken down into other substances. Between 1557 and 1925, another 76 elements were discovered. We now know that 92 elements exist naturally. In recent years, scientists working in laboratories have been able to make at least another 26 artificial elements. We'll shortly look at how all these natural and artificial elements are arranged based on their properties.

KEY IDEA

An element is a pure substance made up of only one type of atom. Ninety-two natural elements were discovered by 1925. Scientists have since created at least 26 artificial elements. Elements are organised based on their properties.

DISCUSSION

Discuss the similarities and differences between the work of the alchemists and the real scientists of the seventeenth century.

EXTENSION: Mercury poisoning

In days gone by, substances containing the element mercury were used to make hats. In those days it was not known that mercury is a very poisonous element. Poisoning by mercury can affect your nervous system and your mind. This sometimes happened to hat makers who were exposed to mercury for a long time; hence the expression 'mad as a hatter'!

FIGURE 4.4 Hat makers at work

4.2.2 Examining elements

Most of the substances around you are made up of two or more elements. Most of the elements are not stable in their pure elemental form and so you will not be able to find many of the 92 naturally occurring elements in their pure, uncombined form. It is possible, however, to examine many of the elements in the school laboratory.

Many elements are safe to handle; however, there are also many that are not. The elements sodium, potassium and mercury, for example, need special care and handling. Sodium and potassium are soft metals that can be cut with a knife. They both get very hot and can cause an explosion when they come into contact with water. Therefore, they are stored under oil so that water in the atmosphere cannot reach them.

INVESTIGATION 4.2

Checking out appearances of elements

Aim

To examine and describe the properties of a selection of elements

Materials

- samples of chemical elements (e.g. carbon, sulfur, copper, iron, aluminium, silicon)
- magnifying glass or stereo microscope
- iron nail

Method

1. Copy the table in the results section into your workbook or obtain a copy from your teacher.
2. Using a periodic table, write the names and symbols of each of the elements.
3. Carefully examine the appearance of each of the elements in the set (look for colour, texture).
4. Test the hardness by scratching with a nail where possible.
5. Find out where the substance might be found.
6. Complete the table by filling in the description. Research or discuss with other students the substances that might include the element. One example is completed for you.

Results

Element	Symbol	State	Observations	In which substances might the element be present?
Hydrogen		Gas	Clear, colourless	Acids, water

Discussion

1. Describe any similarities between the elements.
2. Divide the elements into groups according to one of the properties that you observed. Give the groups names.
3. Identify the element that was hardest to classify.
4. Discuss the accuracy of the test for hardness.
5. Suggest another test that could be performed to find out more about the elements.

Conclusion

Summarise the properties that you observed.

4.2 Activities

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4.2 Quick quiz on	4.2 Exercise

■ LEVEL 1	■ LEVEL 2	■ LEVEL 3
1, 2, 5, 6	3, 8, 9	4, 7, 10

Remember and understand

1. MC An element is:
   A. a substance that cannot be combined with other substances.
   B. a substance that cannot be broken down.
   C. a substance that is only stable in its pure form.
   D. a substance that is only stable in a combined form.
2. Fill in the blanks to complete the sentence.

   Despite __________ never finding the answers they were looking for, they did discover many things about the substances around them. While mixing potions and chanting spells, they tried to change ordinary __________ into __________.
3. **Explain** why sodium and potassium need to be stored under oil.
4. **Identify** whether the following statements are true or false. **Justify** any false responses.

Statement	True or false?
a. Mercury is a poison that affects your nervous system and can cause brain damage.	
b. Substances containing mercury were once used in the process of hat-making.	
c. Mercury is a solid at room temperature.	

5. Classify the following as either correct or incorrect observations of the seventeenth-century scientist shown in figure 4.3.
   a. The scientist has white hair and a beard.
   b. The scientist has his right hand on the table.
   c. The scientist is wearing green and purple robes.
   d. The scientist is wearing a baseball cap.
   e. The scientist is sitting in front of a mortar and pestle.
   f. There are several potions on the table.

Apply and analyse

6. MC Select one reason for displaying chemical safety symbols at the entrances of many buildings.
   A. Chemical safety signs let manufacturers know which chemicals are used in the building so they can be more easily ordered when they run out.
   B. Chemical safety signs let cleaners know which chemicals are stored and used in the building.
   C. Chemical safety signs warn people of the dangers of chemicals stored and used in the building.
   D. Chemical safety signs let delivery people know which chemicals to deliver to the building.
7. **Compare** the properties of a metallic element (e.g. iron) and a non-metallic element (e.g. oxygen). How do these differences in properties influence their use in everyday life? **Explain** your answer with a specific example.
8. **Compare** the scientists of today with the alchemists of the seventeenth century.

Evaluate and create

9. SI Many years ago, balloons were filled with hydrogen so that they could float high in the sky. However, hydrogen is no longer used in balloons because it explodes too easily. At fairs and carnivals, you can often buy colourful gas-filled balloons. These balloons are filled with an element called helium. Why do you think helium is now used in balloons instead of hydrogen? **Explain** your answer.
10. SI **Suggest** why you think mercury was important to alchemists. Based on what you know, **state** some of the uses and safety concerns of mercury.

Answers and sample responses are available in your digital formats.

LESSON 4.3 Elements — the inside story

LEARNING INTENTION

In this lesson you will:
- describe how the model of the atom developed
- describe sub-atomic particles and apply chemical symbols.

4.3.1 Atoms and elements

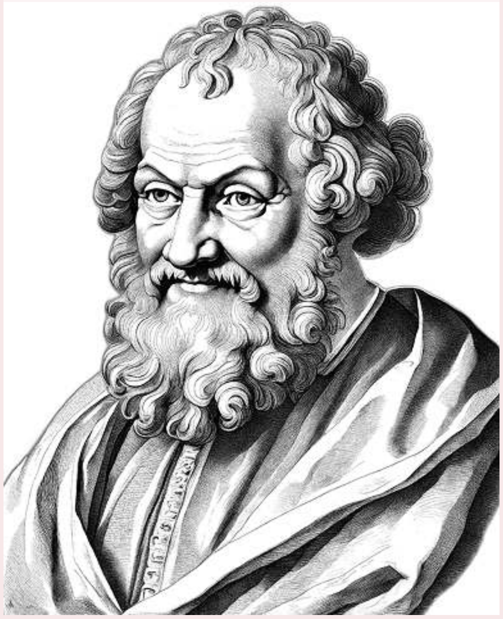
SCIENCE AS A HUMAN ENDEAVOUR: Developing models of the atom

Democritus

About 2500 years ago a teacher named Democritus lived in ancient Greece. He walked around the gardens with his students, talking about all sorts of ideas.

Democritus suggested that everything in the world was made up of tiny particles so small that they could not be seen. He called these particles *atomos*, which means 'unable to be divided'. Other thinkers at the time disagreed with Democritus. It took about 2400 years for evidence of the existence of these atoms (as we now call them) to be found.

FIGURE 4.5 Democritus (*c*.460–*c*.370 BCE), an ancient Greek philosopher



John Dalton

Even though the atom couldn't be seen, scientists did experiments over many years and they thought carefully about the information they gathered.

Finding evidence for the existence of atoms was not possible until Galileo wrote about the need for controlled experiments, and the importance of accurate observations and mathematical analysis, in the sixteenth century. Galileo's 'scientific method', along with the development of more accurate weighing machines, was used by John Dalton in 1803 to show that matter was made up of atoms. He proposed that atoms could not be divided into smaller particles and that atoms of different elements had different masses.

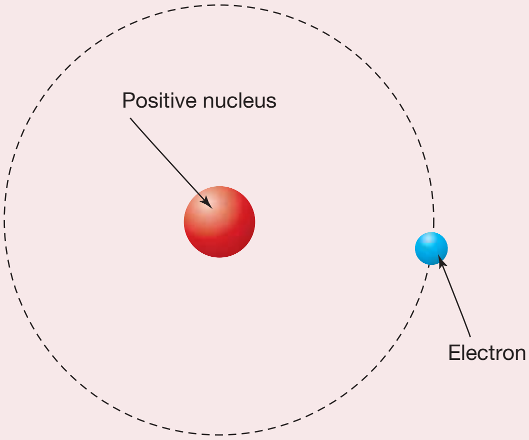
FIGURE 4.6 John Dalton (1766–1844), an English chemist, physicist and meteorologist

Ernest Rutherford

For the next 100 years, scientists thought the atom was a solid sphere, but discoveries including radioactivity and electric current, and new technology such as the vacuum tube and Geiger counters, allowed scientists to 'peek' inside. In 1897 Joseph Thomson, a British physicist, discovered the electron and, a few years later in 1911, New Zealander Sir Ernest Rutherford used some of the new discoveries and inventions to prove that atoms were not solid particles.

Rutherford fired extremely tiny particles at a very thin sheet of gold. Most of the particles went straight through. Only sometimes did they bounce off as if they had hit something solid. He concluded that the tiny particles could be getting through only if each atom consisted of mostly empty space with a positive nucleus at the centre.

FIGURE 4.7 Rutherford's model of the atom



Niels Bohr

Niels Bohr proposed the next model of the atom. He suggested that the electrons circled the nucleus in shells, and that in the first shell there were two electrons and in the second shell up to eight electrons.

In 1932, James Chadwick found another type of particle in the nucleus of the atom — the neutron.

FIGURE 4.8 Bohr's model of the atom

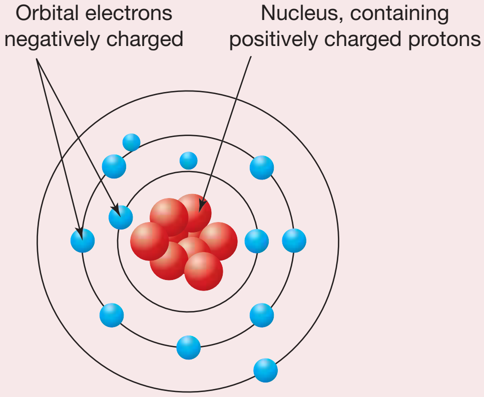
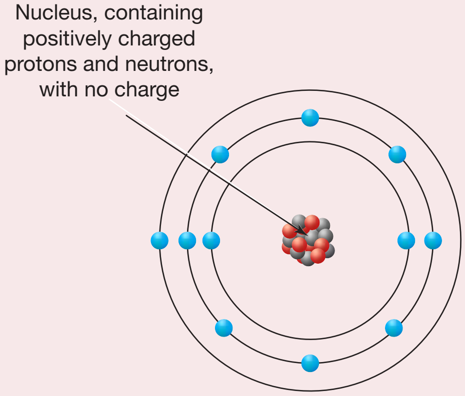


FIGURE 4.9 The Chadwick–Bohr model of the atom



1. How did new tools and technology, such as the vacuum tube or Geiger counter, allow scientists to refine the model of the atom?
2. Why is it important for scientists to revise models and theories, such as the atomic model, when new evidence is discovered?
3. What does the development of the atomic model tell us about the collaborative and ongoing nature of scientific investigation?

Scientific knowledge, including models and theories, can change because of new evidence (VC2S8H01)

SCIENCE INQUIRY: Atomic model detective

Aim

To develop investigable questions related to atomic models and evaluate their effectiveness

Task

In this activity, you will explore different atomic models — Dalton's, Thomson's, Rutherford's and Bohr's — and develop your skills in formulating investigable questions.

Start by selecting one atomic model to investigate. Research its key features, strengths and weaknesses, and look for examples of how this model explains atomic behaviour.

As you gather information, focus on identifying gaps or areas of uncertainty in the model. Use these insights to formulate two to three investigable questions that can guide further exploration. For instance, if you choose the Bohr model, you might ask:

- 'How does the Bohr model explain the emission spectrum of hydrogen?'
- 'What evidence supports the idea that electrons occupy specific energy levels?'
- 'In what ways does the Bohr model fall short in explaining complex atoms?'

Once you have your questions, select one to focus on and evaluate how well your atomic model explains the phenomenon. Use evidence from your research to support your claims.

Showcase your atomic model detective work by designing a creative presentation. You can choose one of the formats listed below.

- *Poster:* Design a colourful poster that includes your chosen question, a summary of the atomic model, key examples and your evaluation of how well the model explains atomic behaviour. Add visuals such as diagrams or illustrations!
- *Infographic:* Create an infographic that visually represents the main ideas about your atomic model, including your investigable question, supporting evidence and any limitations. Use engaging graphics and bullet points for clarity.
- *Digital slideshow:* Make a presentation that highlights your findings. Include slides for your question, model summary, examples and your evaluation. Use images, animations and bullet points to make it visually appealing.
- *Video presentation:* If you are feeling creative, you could record a short video (3–5 minutes) where you explain your findings and answer your chosen question. Use props, animations or even a whiteboard to illustrate your points.

Reproducible investigations to answer questions and test hypotheses can be planned and conducted, including identifying independent, dependent and controlled variables where applicable, stating assumptions, recognising and managing risks, considering ethical issues and following protocols when accessing cultural sites and artefacts on Country and Place (VC2S8I02)

4.3.2 Inside the atom — protons, neutrons and electrons

We now know that each element is made of its own particular kind of atom. Gold contains only gold atoms, oxygen contains only oxygen atoms, carbon contains only carbon atoms and so on. But what is it that makes atoms different from one another? To answer this question, we need to know a little bit more about the atom. It is now understood that all atoms are made up of even smaller particles (table 4.1):

- **protons**
- **neutrons**
- **electrons**.

FIGURE 4.10 If helium atoms are lighter than all others except for hydrogen atoms, why do you think that helium is used in blimps?

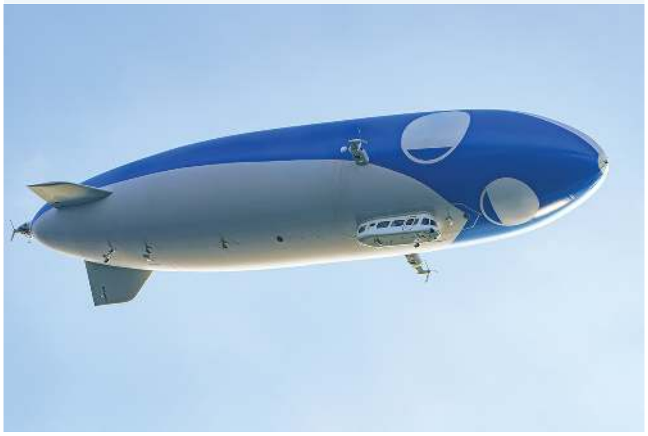
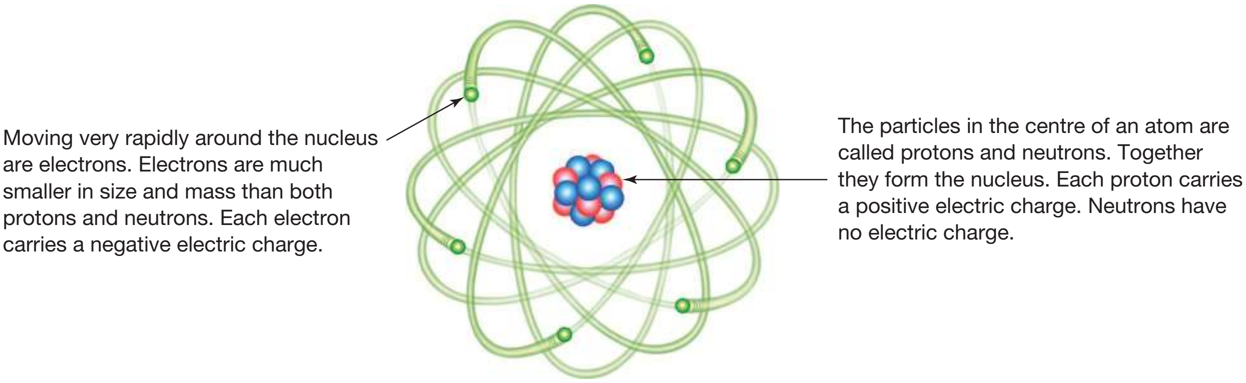


TABLE 4.1 Sub-atomic particles and their properties

Sub-atomic particle	Charge		Relative mass	Location
Proton	Positive	+1	1	Nucleus
Neutron	Neutral	0	1	Nucleus
Electron	Negative	–1	0	Energy shells (orbits; electron cloud)

The amount of negative charge carried by each electron is equal but opposite to the amount of positive charge carried by each proton. Therefore, in an atom, the number of protons is equal to the number of electrons, so there is no overall electric charge.

FIGURE 4.11 Diagram of the atom



KEY IDEA

Matter is made of atoms, which contain protons, neutrons and electrons. Hydrogen is an exception, as most hydrogen atoms lack a neutron. Each atom contains a nucleus consisting of protons and neutrons, with electrons orbiting in energy levels.

4.3.3 Atomic numbers

The number of protons in an atom is called its **atomic number**. Each element has a different atomic number. The blimp in figure 4.10 is filled with helium, which has an atomic number of 2. Helium atoms are lighter than all others except for hydrogen atoms (which have an atomic number of 1). Carbon atoms have six protons inside the **nucleus**, so the atomic number of carbon is 6. The number of neutrons in an atom can vary; most carbon atoms have six neutrons, but some have seven or eight in their nuclei. For each proton in the carbon atom there is also one electron, meaning a carbon atom has six electrons. The lightest element is hydrogen, which has one proton in each atom and an atomic number of 1. The heaviest natural element is uranium, with 92 protons in each atom.

TABLE 4.2 Protons, neutrons and electrons in the first 12 elements

Name	Symbol	Protons (atomic number)	Electrons	Neutrons*
Hydrogen	H	1	1	0
Helium	He	2	2	2
Lithium	Li	3	3	4
Beryllium	Be	4	4	5
Boron	B	5	5	6
Carbon	C	6	6	6
Nitrogen	N	7	7	7
Oxygen	O	8	8	8
Fluorine	F	9	9	10
Neon	Ne	10	10	10
Sodium	Na	11	11	12
Magnesium	Mg	12	12	12

*The number of neutrons can vary but this is the most common number of neutrons for these elements.

ACTIVITY: PhET simulation

Access the **PhET simulation: Build an Atom** interactivity in the Resources panel. Explore how changing the number of protons, neutrons and electrons influences the element, charge and mass of the atom built.

KEY IDEA

Each of the elements differ in their number of protons. It is the number of protons in an atom that identifies the element to which it belongs.

EXTENSION ACTIVITY: What is the mass number of an element?

Research to find out what 'mass number' refers to.
Calculate the mass number of the first 12 elements in the periodic table.

4.3.4 Chemical names and symbols

As the early scientists discovered more and more elements, it became increasingly important that they all agreed on what to call them. Each element was given a name and a **chemical symbol**.

The chemical symbols of most elements are very easy to understand. The symbol sometimes starts with the capital letter that is the first letter of the element's name. For some elements that is the complete symbol.

For example:

O = oxygen   C = carbon   N = nitrogen   H = hydrogen

When there is more than one element starting with the same capital letter, a lowercase letter is also used.

For example:

Cl = chlorine   Ca = calcium   Cr = chromium   Cu = copper

If an element has a symbol that doesn't match its modern name, that's because the symbol is taken from the original Greek or Latin name.

For example:

Na = sodium (*natrium*)   Pb = lead (*plumbum*)   Ag = silver (*argentum*)

Hg = mercury (*hydro argyros*)   Fe = iron (*ferrum*)   K = potassium (*kalium*)

SCIENCE AS A HUMAN ENDEAVOUR: Naming the elements

The names and symbols of some of the elements have some interesting origins.

- Einsteinium (Es) is named after the famous scientist Albert Einstein.
- Polonium (Po) was discovered by another famous scientist, Marie Curie. She named polonium after Poland, the country of her birth.
- Helium (He) was first discovered in the Sun. It is named after Helios, the Greek god of the Sun.
- Sodium (Na) was first called by the Latin name *natrium*.
- Lead (Pb) also used to have a Latin name, *plumbum*. That's where the word 'plumber' comes from. The ancient Romans, who spoke Latin, used lead metal to make their water pipes.

FIGURE 4.12 A statue of Polish scientist Marie Curie holding a model of a polonium atom in Warsaw, Poland

1. How does naming elements after scientists, countries or mythological figures help connect science to history, culture and society?
2. Why is it important for scientists worldwide to use the same symbols and names for elements, such as Na for sodium or Pb for lead?
3. How do the origins of element names reflect the relationship between science and the societies or cultures that discovered them?

Communication of scientific knowledge has a role in informing individual viewpoints, and community policies and regulations (VC2S8H04)

INVESTIGATION 4.3

Getting to know atoms

Aim

To investigate and prepare models of atoms

Materials

A selection of craft materials; for example:
- thin card
- coloured paper
- wool
- buttons
- counters
- pipe cleaners
- string
- small beans

Method

1. In a group, discuss, design and produce a 2D or 3D model of an element with an atomic number between 3 and 12.
2. Include the correct placement of protons, neutrons and electrons.
3. Think about the size of the particles.
4. Include labels or a key.
5. Include the symbol and full name.
6. Write five to seven sentences about the discovery, source and use of your element.

Results

Draw a diagram or take a photo of your model. Your teacher may ask you to present your element to the class.

Discussion

1. Outline what you learned about working in a group.
2. Describe how the atoms that the students in the class prepared are similar and how they are different.
3. Describe the ways in which your model differs from a real atom.

Conclusion

Summarise what you learned about atoms.

4.3 Activities

learnon

4.3 Quick quiz (on)	4.3 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 4, 5, 12	6, 7, 10, 11, 13	8, 9, 14, 15, 16

Remember and understand

1. **Recall** the ideas that Democritus had around 2500 years ago about what substances were made up of, and fill in the blanks to complete the sentence.

   Democritus thought that all __________ was made of tiny __________ that could not be __________ and that these particles could not be divided into anything __________. He called these particles __________.

2. **Identify** the number of types of naturally occurring atoms.
3. **Construct** a labelled a diagram of an atom. Ensure you state the location of each of the three parts of an atom.
4. **State** what the atomic number of an element indicates.

Apply and analyse

5. **State** the symbols of each of the following elements: hydrogen, carbon, oxygen, nitrogen, iron, calcium, copper, lead, mercury.
6. **Explain** why carbon atoms have six electrons.
7. MC **Explain** why electrons do not escape from their atoms.
   A. They are repelled from the external environment.
   B. They are attracted to the neutrons in the nucleus.
   C. They are directly bonded to the protons.
   D. They are attracted to the protons in the nucleus.
8. Attribute each of the following discoveries/theories, which were used to learn more about the atom, to the appropriate scientist — Democritus, Dalton, Rutherford or Bohr.
   a. Experimented with shooting tiny particles at a thin sheet of gold and observed that most particles went straight through
   b. Used Galileo's scientific method with an accurate weighing machine to show that matter was made up of atoms
   c. Said 'everything in the world is made up of tiny particles so small they can't be seen'
   d. Determined that electrons circled the nucleus in shells
   e. Proved that atoms were not solid particles
   f. Said 'atoms of different elements had different masses'
   g. Proposed that atoms could not be divided into small particles
   h. Determined that the nucleus had a positive charge
   i. Called the tiny particles 'atomos'
   j. Determined that atoms were made up of mostly space
9. **Describe** what makes up most of every atom.
10. **State** the atomic number of uranium.

Evaluate and create

11. **Compare** the differences between a carbon atom and a uranium atom.
12. a. **Describe** the nucleus of an atom.
    b. **State** the type of electric charge that the nucleus of every atom has.
    c. **Explain** why atoms have no electric charge.
13. **Identify** which element the atom illustrated in figure 4.11 belongs to.
14. **Explain** why it is important for scientists around the world to agree on the names and chemical symbols of the elements.
15. **State** the names and atomic numbers of the elements with the following symbols.

Symbol	Name	Atomic number
Sn		
Au		
Cu		
N		
Ne		
Sr		
Ca		

16. **Construct** a labelled diagram of an atom that has:
    - three protons
    - one neutron
    - an appropriate number of electrons.

Answers and sample responses are available in your digital formats.

LESSON 4.4 Types of elements and the periodic table

LEARNING INTENTION

In this lesson you will:
- recognise the properties of the types of elements in the periodic table
- explain how these metal and non-metal elements are organised in the periodic table into groups and periods.

4.4.1 Grouping elements in common

It is often convenient to group objects that have features in common. Shops provide a good example of this. In a department store, the goods are grouped so that you know where to find them. You go to the clothing section for a new pair of jeans, to the jewellery section for a new watch and to the food section for a packet of potato chips.

Scientists also organise objects into groups. Biologists organise living things into groups. Animals with backbones are divided into mammals, birds, reptiles, amphibians and fish. Geologists organise rocks into groups. The elements that make up all substances can also be organised into two main groups of elements with common characteristics: **metals** and **non-metals**.

FIGURE 4.13 Mercury is the only metal that is liquid at room temperature.

KEY IDEA

The two main types of elements in the periodic table are metals and non-metals.

Metals

The metals have several features in common (figure 4.14). They:
- are solid at room temperature, except for mercury, which is a liquid
- can be polished to produce a high shine or **lustre**
- are good conductors of electricity and heat
- can all be beaten or bent into a variety of shapes; we say they are **malleable**
- can be made into a wire; we say they are **ductile**
- usually melt at high temperatures. Mercury, which melts at –40 °C, is one exception.

FIGURE 4.14 Metals have many characteristic properties.

Non-metals

Only 22 of the elements are non-metals. At room temperature, 11 of them are gases, 10 are solid and 1 is liquid. The solid non-metals have most of the following features in common. They:

- cannot be polished to give a shine like metals; they are usually dull or glassy
- are **brittle**, which means they shatter when they are hit
- cannot be bent into shape
- are usually poor conductors of electricity and heat
- usually melt at low temperatures.

FIGURE 4.15 Common examples of non-metals are sulfur, carbon and oxygen.

Metalloids

Some of the elements in the non-metal group look like metals. One example is silicon. While it can be polished like a metal, silicon is a poor conductor of heat and electricity, and cannot be bent or made into wire. Those elements that have features of both metals and non-metals are called **metalloids**. There are eight metalloids altogether: boron, silicon, arsenic, germanium, antimony, polonium, astatine and tellurium.

FIGURE 4.16 Metalloids are important materials often used in electronic components of computer circuits.

DISCUSSION

Make a list of five items in the classroom that are made of metal. Explain what the property is that led to its use.

EXTENSION ACTIVITY: Exploring metalloids

Prepare a fact sheet on the source, properties and use of one of the eight metalloids previously listed.

INVESTIGATION 4.4

Looking for similarities

Aim

To describe the characteristics of a variety of elements

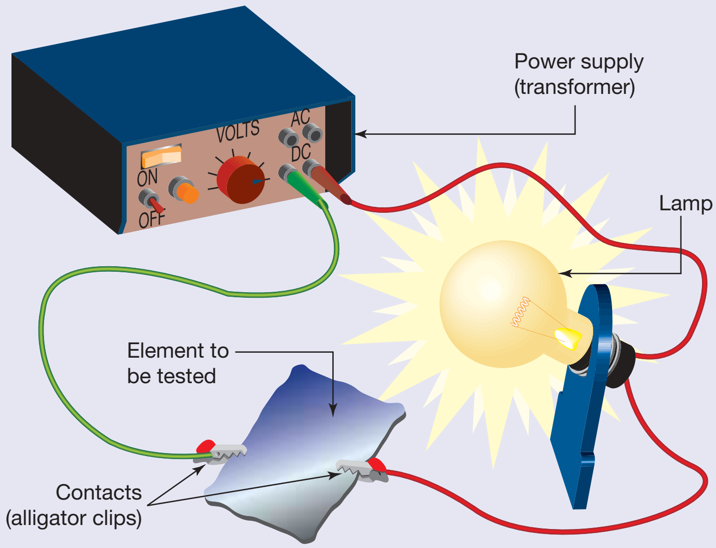
Materials

- safety glasses
- samples of sulfur, zinc, tin, carbon, silicon, copper
- steel wool or very fine sandpaper
- battery or power pack
- wires with alligator clips
- light globe

CAUTION: Power pack safety: Ensure all wires are connected while the power pack is turned off. Set the voltage, and only then turn the power pack on.

Method

1. Make a copy of the table in the results section of this investigation and use it to record your observations for each of the substances.
2. Rub each of the elements with the fine sandpaper and observe whether they are shiny or dull.
3. Try to bend the elements.
4. Connect the circuit as shown in the diagram to determine whether electricity passes through each of the elements.
5. Connect each element sample into this circuit.



Results

Element	Shiny or dull?	Does it bend?	Does it conduct electricity?
Sulfur			
Zinc			
Tin			
Carbon			
Silicon			
Copper			

Discussion

1. Identify the elements that have a shiny surface when polished.
2. Which elements do not have a shiny surface when polished?
3. Identify the elements that can be bent.
4. Identify the elements that cannot be bent.
5. Which elements allow electricity to pass through?
6. Identify the elements that do not conduct electricity.
7. Attempt to divide the elements into two groups based on your observations. Suggest names for these groups.
8. Which of the six elements tested does not seem to fit into either of these two groups?
9. Refer to the aim of this investigation and suggest how the design of this experiment might be improved.

Conclusion

Write sentences that state which substances:

- just had properties of metals
- just had properties of non-metals
- had properties of both metals and non-metals.

4.4.2 Developing the periodic table

As more and more elements were being discovered, the early scientists began to find that some of them had things in common.

SCIENCE AS A HUMAN ENDEAVOUR: Developing the periodic table

The search began for an organised system to classify the chemical elements as they were being discovered. When comparing to the timeline for the discovery of sub-atomic particles, we must remember that the development of the periodic table occurred before the discovery of protons, neutrons and electrons.

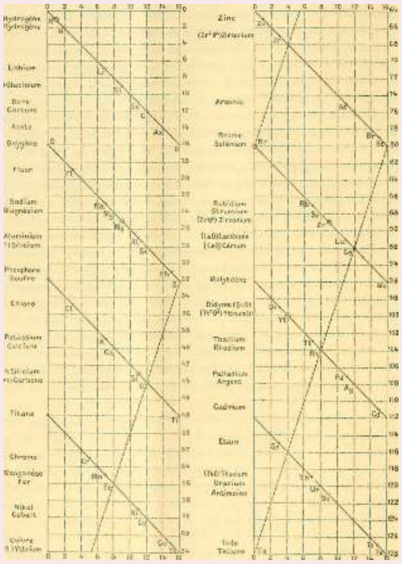
1862 — Alexandre-Émile Béguyer de Chancourtois

Alexandre-Émile Béguyer was a French geology professor who had a small (often not remembered) influence in the field of chemistry in 1862 with his *vis tellurique*, the first periodic representation of known elements (figure 4.17). He identified a repeating, or periodic, pattern of properties with every atomic mass increase of 16.

FIGURE 4.17 a. Alexandre-Émile Béguyer de Chancourtois **b.** His *vis tellurique* from his original publication

a.

b.



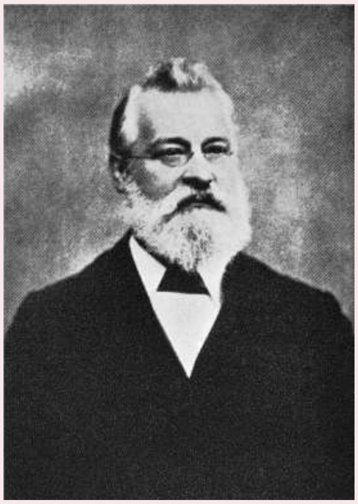
1864 — John Newlands

John Newlands, a British chemist known for his Law of Octaves, noticed similarities in the characteristics of elements that differed by an atomic mass of 7. Despite an octave signifying a difference of 8, it was the similarity of periodicity to music that provided the name. Coincidentally, the noble gases were later discovered and enabled the Law of Octaves to represent a difference in atomic mass by 8.

Unfortunately, there were limitations to Newlands's representation as he did not provide any gaps for elements that were not yet discovered. These limitations led the Chemical Society to not publish his paper, resulting in Mendeleev taking more credit for the discovery. It was not until 1998, over 100 years later, that the Royal Society of Chemistry in England finally recognised Newlands' discovery.

FIGURE 4.18 a. John Newlands **b.** His proposal for the Law of Octaves in the 18th August 1865 edition of *Chemical News* **c.** His arrangement of elements

a.



b.

c.

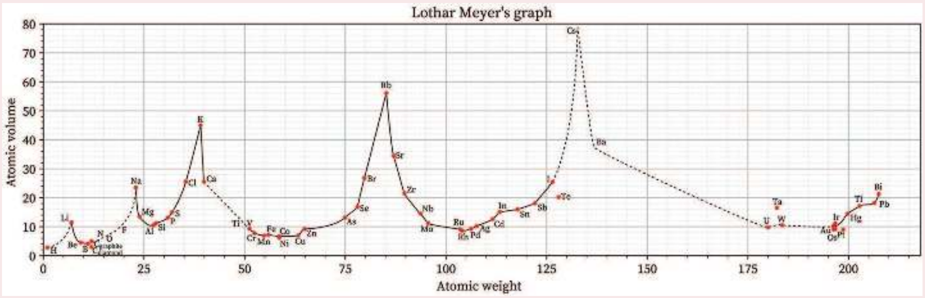
H	Li	Be	B	C	N	O
F	Na	Mg	Al	Si	P	S
Cl	K	Ca	Cr	Ti	Mn	Fe

1864 — Julius Lothar von Meyer

Julius Lothar von Meyer, a German scientist, created several representations of the organisation of the chemical elements, with his first table produced in 1864. He identified the relationship between the atomic mass and the atomic volume for the first 28 elements and this was later extended to 53 elements in 1870 when his paper was published — unfortunately a year after Mendeleev (figure 4.20).

FIGURE 4.19 Julius Lothar von Meyer

FIGURE 4.20 Julius Lothar von Meyer periodic table graph

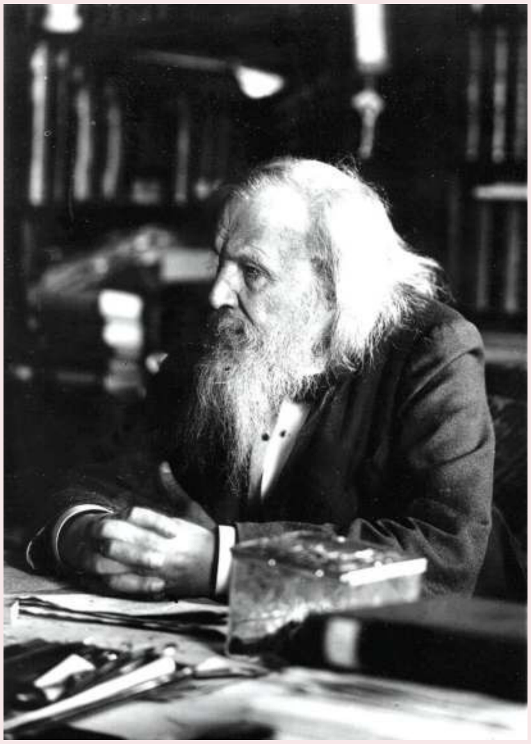


1869 — Dmitri Mendeleev

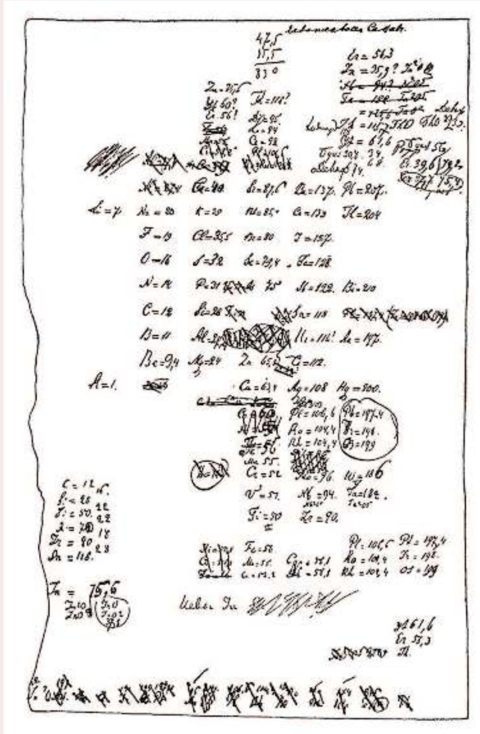
Dmitri Mendeleev, a Russian chemist (figure 4.21), is well known for his representation of the periodic table that formed the basis for the modern periodic table we know today. As opposed to Newlands's octave model, Mendeleev worked out a system for grouping the elements that did take into account gaps where yet undiscovered (predicted) elements should be placed. One predicted element was named 'Eka-aluminium' as it was predicted to be placed after aluminium. Mendeleev had predicted its chemical properties, including the atomic mass, density and melting point, which matched extremely closely to gallium when it was discovered in 1875 by Paul-Émile Locoq de Boisbaudran.

FIGURE 4.21 a. Dmitri Mendeleev **b.** His rough periodic table notes in 1869 **c.** His table as revised in 1871

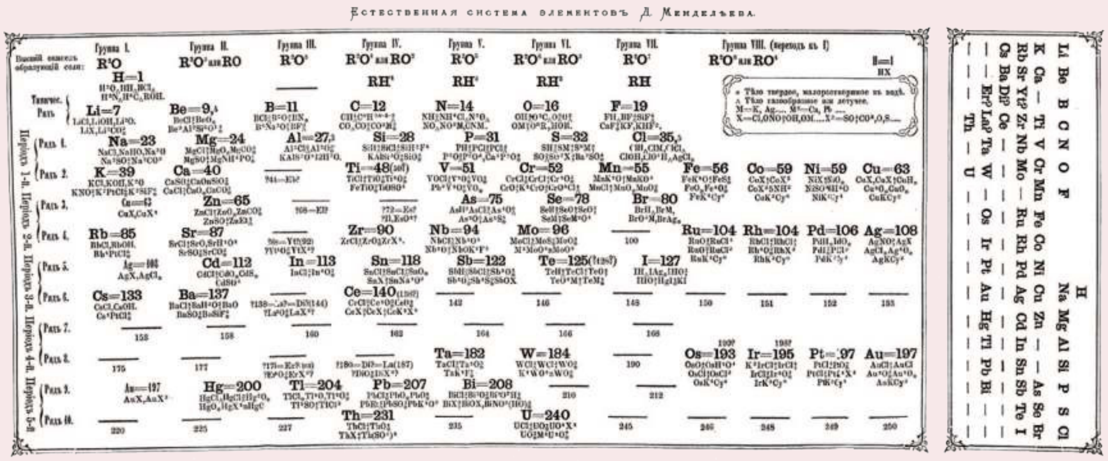
a.



b.



c.



Since Mendeleev's periodic table, there have been numerous attempts to re-create the periodic table as an organised system of chemical elements that takes into consideration both physical and chemical properties; however, it is still Mendeleev's periodic table that forms the basis of the modern periodic table.

Alternative versions of the periodic table

FIGURE 4.22 Left-step periodic table (1928)

Left-step periodic table (by Charles Janet)

	f1	f2	f3	f4	f5	f6	f7	f8	f9	f10	f11	f12	f13	f14	d1	d2	d3	d4	d5	d6	d7	d8	d9	d10	p1	p2	p3	p4	p5	p6	s1	s2
1s																															H	He
2s																															Li	Be
2p 3s																									B	C	N	O	F	Ne	Na	Mg
3p 4s																									Al	Si	P	S	Cl	Ar	K	Ca
3d 4p 5s															Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	Rb	Sr
4d 5p 6s															Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	Cs	Ba
4f 5d 6p 7s	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	Fr	Ra
5f 6d 7p 8s	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og	119	120
	f-block														d-block										p-block						s-block	

FIGURE 4.23 Periodic snail (1964)

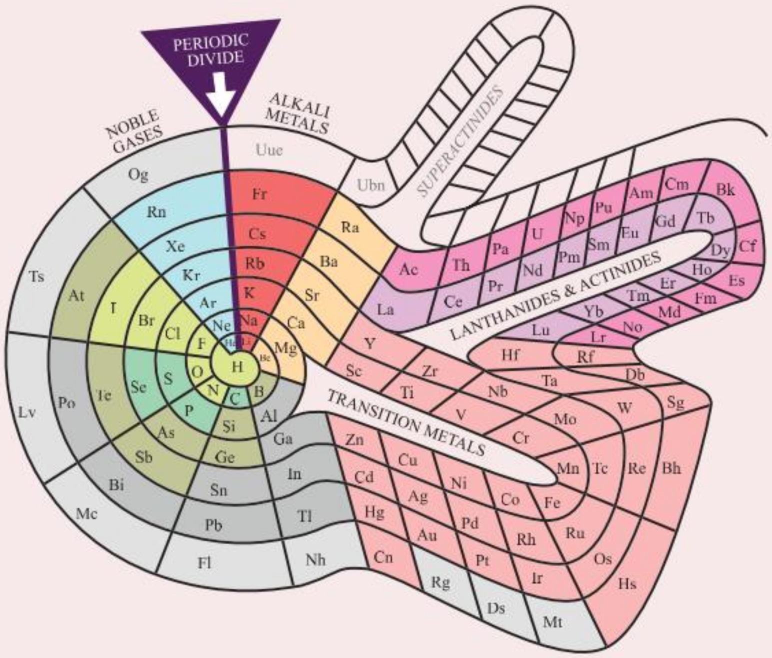


FIGURE 4.24 Curled ribbon (1975)

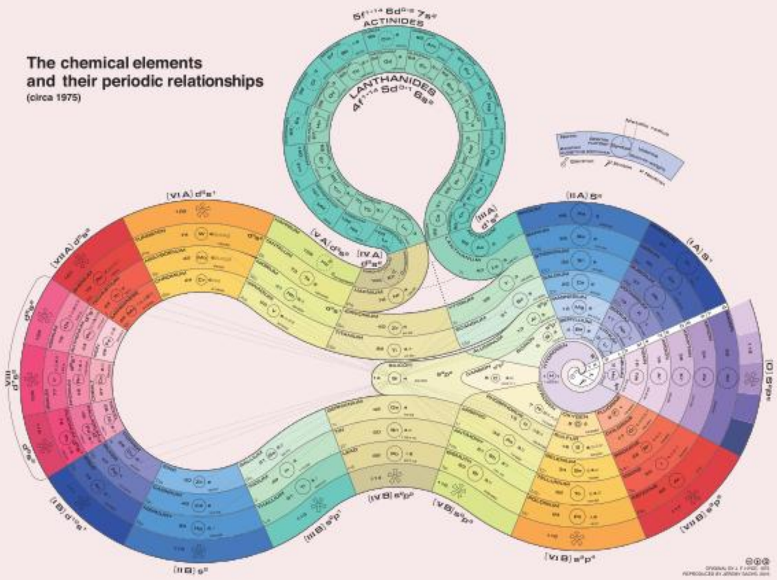
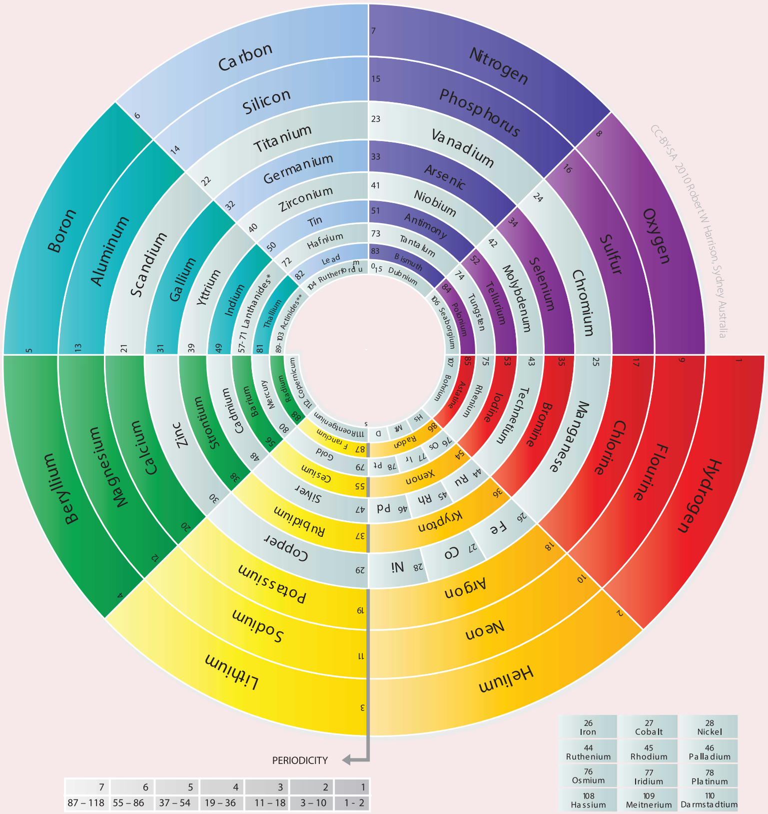


FIGURE 4.25 Circular representations



1. How did the different approaches of Béguyer de Chancourtois, Newlands, Meyer and Mendeleev contribute to the development of the periodic table?
2. Why is it important for scientists from different fields and countries to collaborate when trying to solve complex problems, such as classifying the elements?
3. What can the story of the periodic table teach us about the value of recognising contributions from different scientists, even if their work is not immediately accepted?

Multidisciplinary endeavours to advance scientific knowledge make use of people's different perspectives and worldviews (VC2S8H02)

ACTIVITY: Exploring different forms of the periodic table

In a small group, investigate a specific form of the periodic table, such as the standard periodic table, long form or left-step periodic table. Research and gather information about your chosen table's description, key features, differences, and advantages or disadvantages. Present your findings as a group to the class.

4.4.3 The modern periodic table

Referring to the large modern **periodic table**, note that a vertical column in the table is called a **group**. Elements in the same group in the periodic table always have some features in common. Sometimes these common features are easy to observe, but some of the similarities are not so obvious. For example, neon and argon are gases that do not change when mixed with other elements except under extreme circumstances. They are said to be **inert**. These two gases are found in the last group (group 18) of the periodic table along with the other inert gases. The group containing the inert gases is called the **noble gas** group.

Alkali metals → Group 1

Alkaline earth metals → Group 2

Key

Period 1	79 Gold **Au** **197.0**

- 79 — Atomic number
- Gold — Name of element
- Au — Symbol of element
- 197.0 — Relative atomic mass

Transition metals (Groups 3–9)

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9
	1 Hydrogen **H** **1.0**								
Period 2	3 Lithium **Li** **6.9**	4 Beryllium **Be** **9.0**							
Period 3	11 Sodium **Na** **23.0**	12 Magnesium **Mg** **24.3**							
Period 4	19 Potassium **K** **39.1**	20 Calcium **Ca** **40.1**	21 Scandium **Sc** **45.0**	22 Titanium **Ti** **47.9**	23 Vanadium **V** **50.9**	24 Chromium **Cr** **52.0**	25 Manganese **Mn** **54.9**	26 Iron **Fe** **55.8**	27 Cobalt **Co** **58.9**
Period 5	37 Rubidium **Rb** **85.5**	38 Strontium **Sr** **87.6**	39 Yttrium **Y** **88.9**	40 Zirconium **Zr** **91.2**	41 Niobium **Nb** **92.9**	42 Molybdenum **Mo** **96.0**	43 Technetium **Tc** **(98)**	44 Ruthenium **Ru** **101.1**	45 Rhodium **Rh** **102.9**
Period 6	55 Caesium **Cs** **132.9**	56 Barium **Ba** **137.3**	57–71 Lanthanides	72 Hafnium **Hf** **178.5**	73 Tantalum **Ta** **180.9**	74 Tungsten **W** **183.8**	75 Rhenium **Re** **186.2**	76 Osmium **Os** **190.2**	77 Iridium **Ir** **192.2**
Period 7	87 Francium **Fr** **(223)**	88 Radium **Ra** **(226)**	89–103 Actinides	104 Rutherfordium **Rf** **(261)**	105 Dubnium **Db** **(262)**	106 Seaborgium **Sg** **(266)**	107 Bohrium **Bh** **(264)**	108 Hassium **Hs** **(267)**	109 Meitnerium **Mt** **(268)**

Lanthanides

57 Lanthanum **La** **138.9**	58 Cerium **Ce** **140.1**	59 Praseodymium **Pr** **140.9**	60 Neodymium **Nd** **144.2**	61 Promethium **Pm** **(145)**	62 Samarium **Sm** **150.4**	63 Europium **Eu** **152.0**

Actinides

89 Actinium **Ac** **(227)**	90 Thorium **Th** **232.0**	91 Protactinium **Pa** **231.0**	92 Uranium **U** **238.0**	93 Neptunium **Np** **(237)**	94 Plutonium **Pu** **(244)**	95 Americium **Am** **(243)**

The elements in the periodic table are arranged in order of increasing atomic number, beginning with hydrogen. An atom of hydrogen has just one proton in its nucleus. Metals are found on the left and in the centre of the periodic table, and non-metals can be found in the top right-hand side.

KEY IDEA

In the periodic table, ‘groups’ refer to the vertical columns and ‘periods’ refer to the horizontal rows.

Noble gases ↓ Group 18

Halogens ↓ Group 17

Metals | Non–metals | Metaloids

Group 10	Group 11	Group 12	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
								2 Helium **He** **4.0**
			5 Boron **B** **10.8**	6 Carbon **C** **12.0**	7 Nitrogen **N** **14.0**	8 Oxygen **O** **16.0**	9 Fluorine **F** **19.0**	10 Neon **Ne** **20.2**
			13 Aluminium **Al** **27.0**	14 Silicon Si 28.1	15 Phosphorus **P** **31.0**	16 Sulfur **S** **32.1**	17 Chlorine **Cl** **35.5**	18 Argon **Ar** **39.9**
28 Nickel **Ni** **58.7**	29 Copper **Cu** **63.5**	30 Zinc **Zn** **65.4**	31 Gallium **Ga** **69.7**	32 Germanium **Ge** **72.6**	33 Arsenic **As** **74.9**	34 Selenium **Se** **79.0**	35 Bromine **Br** **79.9**	36 Krypton **Kr** **83.8**
46 Palladium **Pd** **106.4**	47 Silver **Ag** **107.9**	48 Cadmium **Cd** **112.4**	49 Indium **In** **114.8**	50 Tin **Sn** **118.7**	51 Antimony **Sb** **121.8**	52 Tellurium **Te** **127.6**	53 Iodine **I** **126.9**	54 Xenon **Xe** **131.3**
78 Platinum **Pt** **195.1**	79 Gold **Au** **197.0**	80 Mercury **Hg** **200.6**	81 Thallium **Tl** **204.4**	82 Lead **Pb** **207.2**	83 Bismuth **Bi** **209.0**	84 Polonium **Po** **(210)**	85 Astatine **At** **(210)**	86 Radon **Rn** **(222)**
110 Darmstadtium **Ds** **(271)**	111 Roentgenium **Rg** **(272)**	112 Copernicium **Cn** **(285)**	113 Nihonium **Nh** **(280)**	114 Flerovium **Fl** **(289)**	115 Moscovium **Mc** **(289)**	116 Livermorium **Lv** **(292)**	117 Tennessine Ts **(294)**	118 Oganesson **Og** **(294)**

64 Gadolinium **Gd** **157.3**	65 Terbium **Tb** **158.9**	66 Dysprosium **Dy** **162.5**	67 Holmium **Ho** **164.93**	68 Erbium **Er** **167.26**	69 Thulium **Tm** **168.93**	70 Ytterbium **Yb** **173.04**	71 Lutetium **Lu** **174.97**
96 Curium **Cm** **(247)**	97 Berkelium **Bk** **(247)**	98 Californium **Cf** **(251)**	99 Einsteinium **Es** **(252)**	100 Fermium **Fm** **(257)**	101 Mendelevium **Md** **(258)**	102 Nobelium **No** **(259)**	103 Lawrencium **Lr** **(262)**

DISCUSSION

1. Why is the periodic table called the periodic table?
2. Explain why women have been under-represented in the history of science.

EXTENSION ACTIVITY: Alternative periodic tables

Research to see whether you can find any other representations of the periodic table besides those shown already. Can you determine how they grouped the elements?

4.4 Activities

learnon

4.4 Quick quiz on	4.4 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 4, 8	5, 7, 9, 11, 15	6, 10, 12, 13, 14

Remember and understand

1. **Identify** whether each of the following properties are consistent with metals or non-metals.
   a. Are brittle (shatter when hit)
   b. Can be polished to produce a metallic lustre
   c. Can be made into a wire (ductile)
   d. Melt at low temperatures
   e. Are poor conductors of electricity and heat
   f. Can be beaten into a shape (malleable)
   g. Do not have a metallic lustre
   h. Are good conductors of electricity and heat
2. Fill in the blanks to complete the sentence about metalloids.
   Metalloids are ___________ that have features of both ___________ and ___________. Examples include silicon, ___________, arsenic, germanium, antimony, astatine and tellurium.
3. **Recall** which metal is liquid at room temperature.
4. Complete the table by stating the symbols for the following elements.

Element	Symbol	Element	Symbol
a. Hydrogen		f. Tin	
b. Carbon		g. Calcium	
c. Oxygen		h. Sulfur	
d. Nitrogen		i. Copper	
e. Iron		j. Krypton	

5. Review a copy of the periodic table.
   a. Write in it the symbols of the elements that you have already come across in this topic.
   b. Label the groups and periods.
   c. Label the names of groups 1, 2, 17 and 18.
   d. Colour the metals, metalloids and non-metals different colours and include a key.
6. **Identify** what is similar about all of the gases in the noble gas group of the periodic table.

Apply and analyse

7. MC What does 'metallic lustre' mean?
   A. Able to be drawn out into wires
   B. Shiny or a high level of light reflection
   C. Able to be beaten or bent into different shapes
   D. Melts at a very high temperature
8. **State** the name, symbol and number of protons for the element with atomic number 74.
9. Refer to the periodic table. Using the information provided, **state** the number of protons and electrons that are present in a chlorine atom.
10. **Suggest** an element that would have similar properties to calcium. **Explain** your reasoning.

Evaluate and create

11. While all metals have similar characteristics, there are also differences between them. **Describe** three ways in which metals can differ from one another.
12. Silicon is used in the 'chips' of computer circuits, but it is never used in the connecting wires of electric circuits. **Explain** why.
13. SI Imagine that you are a scientist who has discovered what appears to be a new element. It is golden in colour and very shiny. What experiments would you do to test whether it was a metal or non-metal? What results would you expect to get if it was a metal?
14. SI **Explain** why you think Marie Curie's discovery of polonium was important for medicine.
15. Make up a 'Guess the element' card game, finding out and using information about the first 18 elements.

Answers and sample responses are available in your digital formats.

LESSON 4.5 Compounding the situation

LEARNING INTENTION

In this lesson you will describe the difference between elements, compounds and mixtures and that, unlike compounds, there cannot be a fixed chemical formula for mixtures.

4.5.1 Elements, compounds and mixtures

There are millions and millions of different substances in the world. They include the paper of a book, the ink in the print, the air in the room, the glass in the windows, the wool of your jumper, the cotton and polyester in your shirt or dress, the wood of your desk, the paint on the walls, the plastic of your pen, the hair on your head, the water in the taps and the metal of your chair legs. The list could go on and on.

All substances can be placed into one of three groups:

- elements
- compounds
- mixtures.

It is not always possible to tell whether a substance is an element, compound or mixture by just looking at it; you need to have more information. Oxygen and carbon dioxide, for example, are both colourless gases, but oxygen is an element and carbon dioxide is a compound. Water and seawater look the same, but water is a compound and seawater is a mixture.

KEY IDEA

- Elements are made up of one type of atom.
- Compounds are made up of two or more different types of atoms that are chemically combined.

FIGURE 4.26 A compound is completely different from the elements of which it is made. Pure table salt is a compound that consists of the elements sodium and chlorine.

Elements

As you have just seen in lesson 4.4, elements are substances that contain only one type of atom, and it is the elements that make up the periodic table.

- Very few substances exist as pure elements (as most elements are not stable on their own — they bond with other atoms to form compounds that make them stable).
- Most substances around us are either compounds or mixtures.
- Examples of elements are hydrogen, oxygen, carbon and iron.

Compounds

Compounds are usually very different from the elements of which they are made.

- In compounds, the atoms of one element are **bonded** very tightly to the atoms of another element or elements.
- The elements that make up a compound are completely different substances from the compound itself. For example, pure salt (sodium chloride) that you might put on your French fries is a compound made up of the elements sodium (a silvery metal) and chlorine (a green, poisonous gas).

- A compound always contains the same relative amounts of each element. For example, the compound carbon dioxide is always made up of two atoms of oxygen for each atom of carbon. Its chemical formula is therefore CO_2. The compound sodium chloride always has one sodium atom for each chlorine atom and its formula is simple: NaCl.
- Every compound has a formula comprising the symbols of the elements that make it up. Unlike mixtures, the elements within a compound cannot easily be separated from each other. When the atoms of different elements bond together during a chemical reaction, a compound is formed. When the elements iron and sulfur are heated together, they form a new compound called iron sulfide. Iron sulfide has the formula FeS.
- Elements can be separated from compounds in several ways. These include:
  - passing electricity through a compound (see section 4.5.3)
  - strongly heating the compound
  - mixing the compound with other chemicals.

  Each of these methods involves a chemical reaction in which completely different substances are formed.

KEY IDEA

The word 'compound' comes from the Latin word *componere*, meaning 'to put together'.

Mixtures

A mixture is a combination of substances in which each keeps its own properties; that is, they are not chemically bonded.

FIGURE 4.27 A mixture of lollies

Mixtures can be made up of:
- two or more elements
- two or more compounds
- a combination of elements and compounds in any states of matter (solid, liquid or gases).

Consider the image of lollies shown in figure 4.27. There are more than two types of lollies pictured, all in the solid state. We can therefore say that it is a mixture of lollies. Can you determine how many different types of lollies are in the mixture?

Different types of mixtures include:
- solutions
- suspensions
- colloids.

Solutions

A solution is a liquid mixture in which the **solute** is the **dissolved** substance in the solution, while the **solvent** is the substance that the solute dissolves into. Together the solute and the solvent form a **homogeneous** solution. This means that it has uniform composition and properties throughout the whole solution. If the solvent is water, the solution is known as an **aqueous** solution. When sugar is dissolved in a cup of tea, for example, an aqueous solution is formed. Our survival is dependent on reactions that occur in aqueous solutions inside and outside the cells in our bodies.

FIGURE 4.28 Dissolving sugar (solute) in a cup of tea (solvent), forming an aqueous solution

Suspensions

A **suspension** is a mixture in which solid substances do not dissolve and are dispersed throughout the volume of the liquid. This is an example of a **heterogeneous** mixture. For example, looking at the glass of muddy water in figure 4.29, you can see the solid sediment at the bottom of the glass and some of the dirt still suspended in the solution as it is slowly settling to the bottom. You can see the suspended particles with your naked eye.

FIGURE 4.29 Muddy water forms a suspension.

Colloids

A **colloid** is a mixture in which a microscopically insoluble substance is dispersed and suspended throughout another substance. The particles cannot be seen by the naked eye. A common example of a liquid colloid is milk, and in 1857, Michael Faraday made a gold colloid sample (figure 4.30).

Properties of mixtures

- Unlike compounds, the parts of a mixture are not always in the same proportion (because in a mixture the components are not bonded together, so you can add as much or as little of each substance). For example:
  - seawater is the most common mixture on Earth's surface, but the percentage of salt is not always the same. Seawater can also include a variety of other elements and compounds in different quantities.
  - a coffee drink is a mixture that can contain different relative amounts of water, milk, coffee and sugar
  - brass is a mixture of metals that can have different relative amounts of copper and zinc.
- As the components are not bonded to each other, there can be no unique chemical formula for mixtures; however, you can determine the percentage of each component in the mixture.
- The substances that make up mixtures can usually be easily separated from each other (except for in colloids).
- When the parts of a mixture are separated, no new substances have been formed as no chemical reaction has taken place. For example, fizzy soft drink contains water, gas, sugar and flavourings. If you shake the soft drink, the gas bubbles separate from the water and go into the air. You still have the water in the bottle and the gas in the air; they are just not mixed together anymore. The parts of the mixture can be separated relatively easily. The gas escapes when the lid of the container is opened, and the water can be separated by evaporation, leaving behind sugar and some other substances.

FIGURE 4.30 A sample of gold colloid made by Michael Faraday in 1857.

KEY IDEA

There can be no unique chemical formula for mixtures because, unlike compounds, the parts of a mixture are not always in the same proportion.

SCIENCE INQUIRY: Investigating properties of substances

Aim

To formulate investigable questions related to elements, compounds or mixtures

Task

In this activity, you will choose a substance to research, formulate questions, discuss your findings and write a reflection.

1. Select an element, a compound or a mixture to research.
   - Elements (e.g. gold, oxygen)
   - Compounds (e.g. water, sodium chloride)
   - Mixtures (e.g. saltwater, air)
2. Briefly research your chosen substance to understand its characteristics.
   - For elements: Investigate atomic structure, symbols and properties.
   - For compounds: Look at chemical formulas, how they are formed and their properties.
   - For mixtures: Explore how mixtures are formed, their components, and whether they are homogeneous or heterogeneous.
3. Based on your research, create three to four investigable questions. Use these prompts to guide your thinking:
   - 'How does the combination of [element] and [element] create a compound with different properties?'
   - 'What are the observable differences between a mixture of [substance A] and [substance B] compared to a compound made from them?'
   - 'What methods can be used to separate the components of a mixture like [specific mixture]?'
4. Pair up with a classmate to share your questions. Discuss the relevance and potential experimental approaches to answer each question.
5. Write a short reflection (three to four sentences) on how formulating these questions enhances your understanding of the differences between elements, compounds and mixtures.

Reproducible investigations to answer questions and test hypotheses can be planned and conducted, including identifying independent, dependent and controlled variables where applicable, stating assumptions, recognising and managing risks, considering ethical issues and following protocols when accessing cultural sites and artefacts on Country and Place (VC2S8I02)

DISCUSSION

Substance X is a blue colour. When it is heated a gas is given off, leaving a black solid.

Is substance X an element or a compound?

Table 4.3 lists some common substances and identifies whether they are an element, compound or mixture.

TABLE 4.3 Some common substances

Substance	Type	Composed of	Scientific name
Gold	Element	Gold	Gold
Diamond	Element	Carbon	Carbon
Water	Compound	Hydrogen and oxygen	Dihydrogen monoxide
Pure salt	Compound	Sodium and chlorine	Sodium chloride
Brass	Mixture	Copper and zinc	Brass
Soft drink	Mixture	Water, sugar, carbon dioxide and other compounds	
Seawater	Mixture	Water, sodium chloride and other compounds	

EXTENSION ACTIVITY: What is air a mixture of?

Air is a mixture. Find out what substances are present, whether they are elements or compounds, and how much of each substance is present.

INVESTIGATION 4.5

Making a compound from its elements

Aim

To use a chemical reaction to make a compound from its elements

Materials

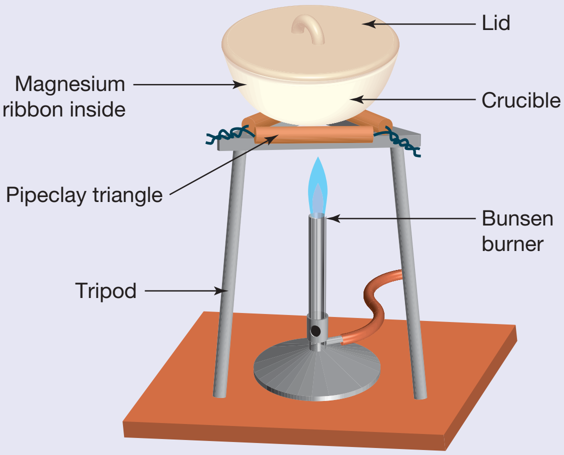
- 4–5 cm strip of clean, shiny magnesium ribbon. It can be coiled to fit in the crucible.
- crucible with lid
- pipeclay triangle, tongs and safety glasses
- Bunsen burner, heatproof mat and matches
- emery paper
- electronic scales

CAUTION: Do not stare at the magnesium ribbon while it is burning as it can cause temporary blindness.

A lab coat and safety glasses should be worn while conducting this experiment.

Method

1. Examine the piece of magnesium and note its appearance before placing it in the crucible and covering it with the lid.
2. Put the crucible on the pipeclay triangle as shown in the diagram.
3. Heat the crucible with a strong blue flame, monitoring the reaction by occasionally lifting the lid a little with tongs.
4. When all the magnesium ribbon has been changed, turn off the flame and leave the crucible on the tripod to cool.



Results

Record your observations of the magnesium before heating and the substance in the crucible after heating.

Discussion

1. State whether magnesium is an element or a compound. Justify your response.
2. Name the other reactant in this experiment, aside from magnesium.
3. Classify the substance remaining in the crucible as either an element or a compound. State its name.
4. Identify the evidence that indicates a new substance has been produced.
5. Explain a reason, besides checking if the reaction is complete, for lifting the crucible lid slightly with tongs during the burning.
6. Predict whether the mass of the crucible contents will be the same, higher or lower after heating. Justify your answer.

Conclusion

Describe and name the compound formed.

4.5.2 Bonding

The naturally occurring elements (of metals, non-metals and metalloids) are the building blocks of everything in our world. The atoms of various elements join together (bond) in a wide variety of ways to produce many compounds. Elements and compounds can be combined in many ways to make countless mixtures.

Atoms can join, or bond, in many different ways. In some substances, atoms are joined in groups called molecules. For example, in oxygen gas (O_2), oxygen atoms are joined in groups of two. In the compound carbon dioxide (CO_2), one carbon and two oxygen atoms are joined in every molecule. Atoms can join to form small or large molecules of many different shapes.

There are three main types of bonds between atoms within a compound:
- metallic bonds
- ionic bonds
- covalent bonds.

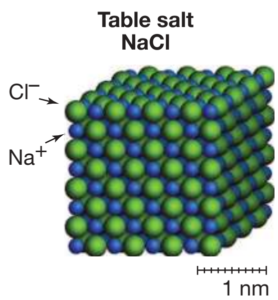
TABLE 4.4 Models representing the molecules of some compounds

Molecule	Chemical formula	Visual representation
Carbon dioxide	CO_2	
Water	H_2O	
Methane	CH_4	

KEY: Red = oxygen, white = hydrogen, black = carbon

Some compounds are not made up of molecules. Instead, the atoms bond by lining up one after the other. This is known as a lattice. In the lattice in figure 4.31, sodium bonds to chlorine, which bonds to sodium and so on. Common table salt is an example of a substance that is bonded in this way.

FIGURE 4.31 The atoms of common table salt bond by lining up one after the other.



KEY IDEA

A molecule consists of two or more atoms chemically joined (bonded) together.

ACTIVITY: PhET simulation

Access the **PhET simulation: Build a Molecule** interactivity in the Resources panel to explore the structure of elements and compounds.

Start by building simple molecules such as H_2O and CO_2, observing how different atoms connect and form bonds. Challenge yourself to create more complex molecules, noting the types of bonds (single, double) and how the molecule's shape changes.

After building your molecules, answer the following reflection questions.

1. Describe what the simulation shows about the arrangement of atoms in a molecule.
2. Explain how the visual representation helps you understand the molecular structure.
3. Discuss the importance of these representations in developing scientific knowledge.

INVESTIGATION 4.6

Modelling elements, compounds and mixtures

Aim

To make models of elements, compounds and mixtures

Materials

- LEGO® blocks that are all the same size, or a molecular kit
- Each block (or ball) represents an atom of the following elements (possible colour key but others are acceptable):
  - White = hydrogen (H)
  - Red = oxygen (O)
  - Black = carbon (C)
  - Blue = nitrogen (N)
  - Green = chlorine (Cl)
  - Yellow = helium (He)

Method

Remember:

- Elements contain only one type of atom.
- When two or more atoms are chemically joined (bonded) together they are called molecules. They can be the same or different atoms.
- Mixtures contain different elements and/or compounds but they are not chemically joined.

1. Draw a key showing the colours used for each element.
2. Draw the table shown in the results section to record your results.
3. Keep two of each model that you make.

Elements

4. A single block represents an atom; a LEGO® helium atom is drawn and coloured in the table.
5. Pick up a handful of yellow blocks; this represents the element helium (He), a noble gas.
6. Join two white blocks together (hydrogen atoms are found in pairs); this is a molecule of hydrogen.
7. Make a few more hydrogen molecules; these represent the element hydrogen (H_2).
8. Oxygen gas also contains atoms that are found in pairs. Make and draw an oxygen molecule (O_2).

Compounds

9. Take a black and a red block and join them together; this is a molecule of carbon monoxide. Draw this molecule in the table.
10. Make a few more carbon monoxide molecules. These represent the compound carbon monoxide.
11. Make a water molecule, H_2O. Draw it in the table. You can place the elements in any order until you learn more about molecules in later years.
12. Make a hydrogen chloride molecule, HCl. Draw it in the table.
13. Now make the following molecules and draw them in the table: CO_2, NO_2, NH_3.

Extension

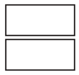
Make the following molecules:
- dinitrogen monoxide (laughing gas, N_2O)
- methane (natural gas, CH_4)
- benzene (in petrol, C_6H_6).

Mixtures

14. Collect the models of elements that you made but DO NOT join them together. This is a mixture of elements. A mixture of elements is shown in the table.
15. Collect the models of compounds that you made but DO NOT join them together. This is a mixture of compounds. Draw it in the table.
16. Collect a few of the models of any of the atoms or molecules that you have made but DO NOT join them together. This is a mixture. Draw it in the table.

Results

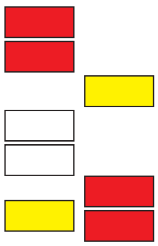
Elements

He (helium atom)		H_2 (hydrogen molecule)		O_2 (oxygen molecule)	

Compounds

CO (carbon monoxide)		H_2O (water)		HCl (hydrogen chloride)	
CO_2 (carbon dioxide)		NO_2		NH_3 (ammonia)	

Mixtures

Mixture of elements		Mixture of compounds		Mixture	

Discussion

1. **a.** State the formula for nitrogen gas, knowing it is made up of pairs of nitrogen atoms.
   b. Describe what a LEGO® model of a nitrogen molecule would look like.
2. **a.** Name the molecule with the formula NO_2.
   b. Determine how many atoms are present in the NO_2 molecule.
   c. Identify how many elements are present in the NO_2 molecule.
3. State the familiar substance with the chemical name dihydrogen monoxide.
4. Construct a LEGO® model representing a hydrogen peroxide molecule, which contains two hydrogen atoms and two oxygen atoms.
5. Explain the difference between elements, compounds and mixtures to a friend, using fruit as examples.

Conclusion

Explain what these models demonstrate about molecules.

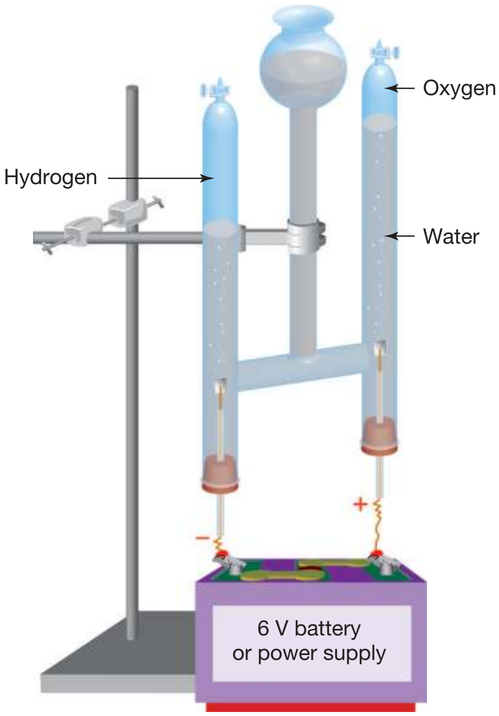
KEY IDEA

- Elements are made up of one type of atom and you will only use one chemical symbol to identify the element. A chemical formula will therefore include at least two different chemical symbols to show they are bonded together as a compound.
- Mixtures contain two or more different elements, compounds or ions; however, they are not chemically bonded and can exist in different amounts, altering their percentage composition.

4.5.3 Splitting water

Water is essential for life and water is everywhere. It is in your taps, in your body, in the rivers, in the sea, in the air and it comes down as rain. You wash in it, cook with it and drink it. You cannot live without water. Water is not an element; it consists of molecules made up of two hydrogen atoms and one oxygen atom (H_2O), and it can be broken down into simpler substances. Figure 4.32 shows an apparatus called a Hofmann voltameter. Water is placed in the voltameter, which is connected to a battery. The electricity splits the water into the elements of which it is made: the colourless and odourless gases hydrogen and oxygen. Hydrogen and oxygen are both elements and have quite different properties from water.

FIGURE 4.32 Water is split in a Hofmann voltameter. The clear gas in the left tube is hydrogen (H_2). The gas in the right tube is oxygen (O_2). What do you notice about the amounts of hydrogen and oxygen that are produced?



Hydrogen

- It is a much less-dense gas than oxygen. This means that a balloon filled with hydrogen will float up very high, but one filled with oxygen will not.
- It is present in almost all acids. By placing a piece of a certain type of metal in an acid, the hydrogen is forced out. The hydrogen can be collected and tested with a flame. This is called the **pop test**.
- When burned, it combines with oxygen in the air to form water. This releases a lot of energy. If large amounts of hydrogen and oxygen are used, enough energy can be released to lift a space rocket.
- It is a possible fuel for the future as it produces water when it burns; however, it needs a cheap form of energy to separate it from water.

Oxygen

- It is the gas that all living things need to stay alive.
- It is necessary for substances to burn — even hydrogen does not burn without it.
- It is present in water, air, rocks and even hair bleach.

INVESTIGATION 4.7

Collecting an element

Aim

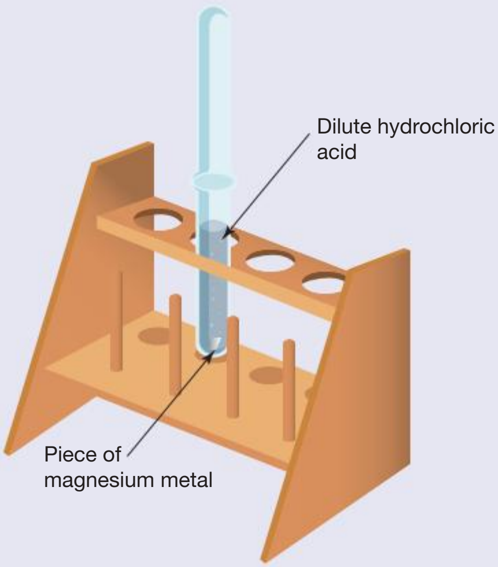
To observe a chemical reaction between a metal and an acid

Materials

- safety glasses
- 2 test tubes and a test-tube rack
- matches
- dilute hydrochloric acid
- measuring cylinder
- magnesium metal

Method

1. Measure 10 mL of hydrochloric acid and pour it into the test tube.
2. Add a piece of magnesium and place the second test tube on top of the first as shown in the diagram. Carefully observe what happens.
3. After one minute, take the second test tube off the first. While it is still inverted, immediately light the gas in the second test tube with a match.



Results

1. Record your observations of what happened when you put the magnesium strip in the test tube with the acid.
2. Record your observations of what happened when you put the match below the upside-down test tube.

Discussion

1. Describe what happened in the test tube containing the metal and the acid.
2. Describe the appearance of the hydrogen gas.
3. Describe what happened when you lit the gas.
4. Look closely at the second test tube. Describe what you see inside it.
5. Compare the properties of the elements that reacted and the compound that was formed.
6. Do you think that all metals and acids would react the same way? Describe some steps that would help you answer this question.

Conclusion

Write a sentence describing what happens when a metal, like magnesium, is added to an acid.

EXTENSION: Carbon — it is everywhere

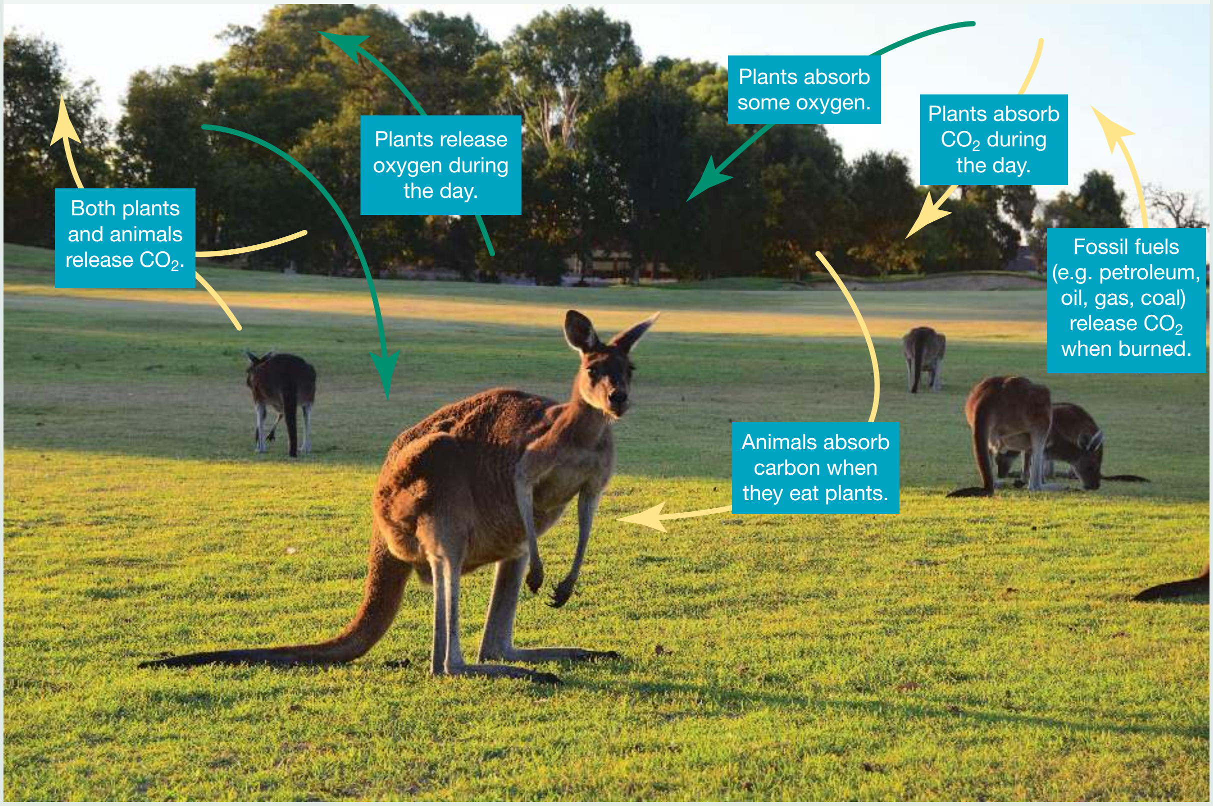
Carbon is a most amazing element. It is found naturally in three different forms. One form is diamond, another is graphite (the 'lead' in lead pencils) and the third is called amorphous carbon (coal, charcoal and soot).

Carbon is also found combined with other elements in a huge range of compounds. No other element forms as many different types of compounds as carbon. Carbon is found in everything from the skin of an elephant to paint on the walls!

The chemistry of life

All living things are made up of compounds including proteins, fats and carbohydrates. The main element in these compounds is carbon. The carbon atoms in living things will eventually become carbon atoms in the air or carbon atoms in limestone under the sea. Figure 4.33 shows how nature constantly recycles carbon atoms.

FIGURE 4.33 Nature constantly recycles carbon atoms.



Plants take in carbon dioxide through their leaves and, in a process known as **photosynthesis**, use the carbon dioxide and water to make sugar. Sugar is a compound made up of carbon, hydrogen and oxygen atoms. Plants use the sugar to make other substances and for energy to grow. Animals eat plants and the carbon atoms then become part of the animals' bodies.

Carbon atoms in the bodies of living things return to the air in several ways: **cellular respiration**, **decomposition** and **burning**.

- Cellular respiration is a process that occurs in the cells of every living thing. It uses glucose and oxygen, and releases energy and produces carbon dioxide. The carbon dioxide that you breathe out contains carbon atoms that were once part of your body.
- Decomposition is what occurs when plant or animal material breaks down, such as in a compost heap or after something is buried. Microscopic living creatures called decomposers absorb some of the substances in the dead material and release carbon dioxide to the air by respiration.
- When substances containing carbon are burned, carbon dioxide is released. Coal, natural gas and oil are all **fossil fuels** formed from living things, and contain carbon atoms. Fossil fuels undergo **combustion**, a reaction with oxygen that releases energy, which you know as burning. The burning of these fuels, as well as bushfires, releases carbon dioxide back to the air.

EXTENSION ACTIVITY: Carbon dioxide levels

Find out why the amount of carbon dioxide in the atmosphere is increasing.

Make five slides summarising your findings.

4.5.4 Compounds of today and tomorrow

Polymer is the name given to a compound made of molecules that are long chains of atoms. Most polymers are made up of chains containing carbon atoms. **Plastics** are synthetic polymers, whereas cotton and rubber are examples of natural polymers. Although scientists first developed polymers in laboratories in the 1800s, it was not until after World War II that most modern polymers were invented. Modern polymers are used in food wrapping, paint, plastic 'glass', polystyrene foam for packaging and cups, banknotes, cases for electronic appliances such as computers and televisions, clothing, glues, shopping bags, sports equipment and even tea bags!

KEY IDEA

The word 'polymer' comes from the Greek word *polymeres*, meaning 'of many parts'.

CASE STUDY: The elements nitrogen and gold

- Nitrogen is an element. It is a clear, colourless gas made up of molecules. Each molecule is made up of a pair of atoms. Nitrogen makes up 80 per cent of the atmosphere, which means that four-fifths of each breath you take is nitrogen. Our bodies cannot use this nitrogen so we breathe it straight out again! The gases oxygen, hydrogen and chlorine also exist as molecules made up of pairs of atoms.
- Gold is the only metal element found in large amounts in its pure form, rather than bonded in compounds with other elements.

FIGURE 4.34 An almost 2 kg nugget of gold found in Australia

DISCUSSION

What are the advantages and disadvantages of the use of plastics in current society?

EXTENSION ACTIVITY: Nanomaterials

Why are very tiny particles called nanomaterials? Find out what they are and where they might be used.

4.5 Activities

learnon

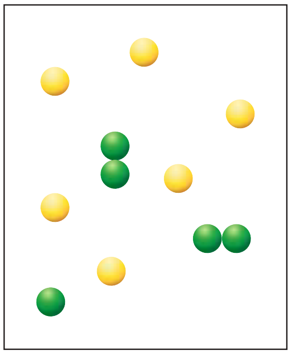
4.5 Quick quiz on	4.5 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 5, 6	4, 7, 11, 12	8, 9, 10, 13, 14

Remember and understand

1. **Identify** the correct word to complete the sentence.
   The elements that are ionically bonded together to form table salt are ___________ and ___________.
2. MC **Identify** how compounds differ from elements.
   A. Compounds contain atoms of more than one type of element.
   B. Compounds contain more than one atom.
   C. Compounds are always solid.
   D. Compounds are not reactive.
3. **Compare** the key difference between a mixture and a compound.
4. **Identify** whether each of the diagrams shown represents an element, a compound or a mixture.

A



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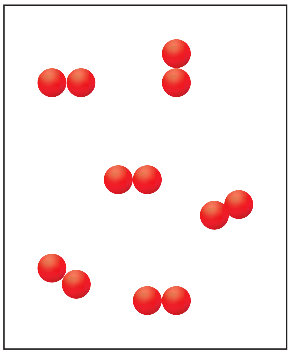

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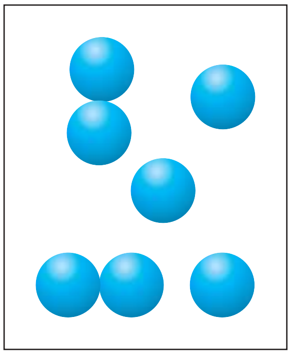

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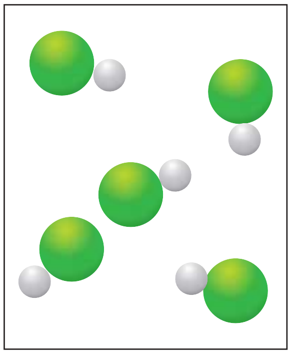

5. a. **Define** the term 'molecule'.
   b. **Name** two elements made of molecules.
   c. **Name** two compounds that are made up of molecules.
6. a. **Define** the term 'polymers'.
   b. **Compare** natural polymers with synthetic polymers. **State** two examples of each.
7. Are all compounds made up of molecules? **Explain** your reasoning.

Apply and analyse

8. SI Fizzy soft drink is a mixture of several compounds. **List** three of the compounds and suggest how each of them could be separated from the mixture.
9. **Identify** the correct word to complete the sentence. Use the following terms:

   chemical, bonded, physical

   If atoms are __________ together, they cannot be separated by __________ methods such as sieving or filtering. They can be separated only by __________ processes.
10. **List** three ways in which elements can be separated from their compounds.
11. Complete the table provided. Use the formula of each compound to work out how many elements are present and which ones they are. (The formula of a compound not only tells you which elements are present, but also indicates the ratio of atoms of the different elements. For example, in the compound NH_3 there are three hydrogen atoms for each nitrogen atom.)

Compound	Formula	Number of elements	Names of elements
Copper sulfate	$CuSO_4$	3	Copper, sulfur, oxygen
Zinc sulfide	ZnS		
Ammonia	NH_3		
Sulfuric acid	H_2SO_4		
Hydrochloric acid	HCl		
Table salt	NaCl		

Evaluate and create

12. **Justify** how you know that water is a compound rather than just a mixture of hydrogen and oxygen.
13. **Compare** the differences between an atom and a molecule. **Define** each term and **explain** their distinct characteristics.
14. SI Australia has led the way in the production of polymer banknotes. **Explain** why you think Australia's production of polymer banknotes is significant.

Answers and sample responses are available in your digital formats.

LESSON 4.6 Review

4.6 Success criteria

Tick the column to indicate that you have completed the lesson and how well you think you have understood it using the traffic light system.

(**Green:** I understand; **Yellow:** I can do it with help; **Red:** I do not understand)

Lesson	Success criteria	Green	Yellow	Red
4.2	I can recognise how the work of scientists today compares with the work of the early alchemists.			
	I can describe the properties of some elements.			
4.3	I can describe how the model of the atom developed.			
	I can describe sub-atomic particles and apply chemical symbols.			
4.4	I can recognise the properties of the types of elements in the periodic table.			
	I can explain how these metal and non-metal elements are organised in the periodic table into groups and periods.			
4.5	I can describe the difference between elements, compounds and mixtures and that, unlike compounds, mixtures cannot have a fixed chemical formula.			

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Post-test Topic 4 Post-test

eWorkbook Topic 4 eWorkbook

Digital document Key terms glossary

4.6 Activities

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4.6 Review questions

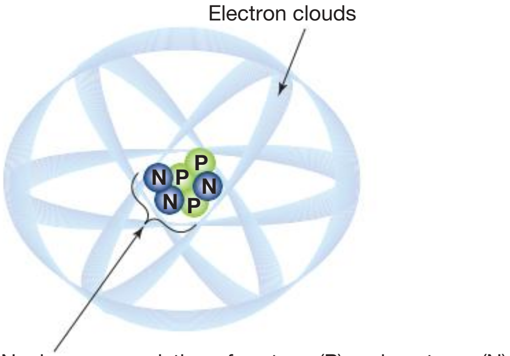
LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 6, 8, 13, 18	4, 5, 9, 10, 12, 15, 19	7, 11, 14, 16, 17, 20, 21

Remember and understand

1. Complete the following table.

Part of atom	Location	Size and mass (relative)	Electric charge
		Large	Positive
Neutron			
	Outside the nucleus		

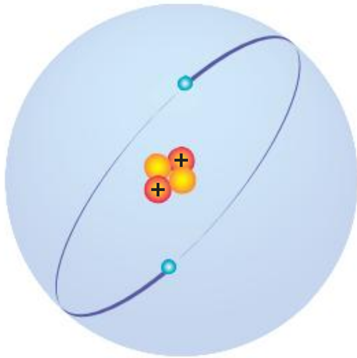
2. **Identify** which element is shown in the diagram.



3. **Determine** the number of electrons in a neutral atom that has 12 protons.
4. **Identify** what occupies most of the space in an atom.
5. MC **Identify** the one feature that every single atom of the element sodium has in common.
   A. Eleven electrons in the electron orbits
   B. Eleven neutrons in the nucleus
   C. Eleven protons in the nucleus
   D. Eleven protons and eleven electrons
6. **State** the atomic number and the number of protons and electrons in each of following elements listed in the table.

	Atomic number	Protons	Electrons
Hydrogen			
Oxygen			
Carbon			
Uranium			

7. Consider the diagram given.
   a. Label an electron and the nucleus on the diagram.
   b. i. How many protons does this atom have?
      ii. How many neutrons does this atom have?
      iii. How many electrons does this atom have?
      iv. What is the atomic number of this atom?
   c. **Describe** one use of the element that is made up of these atoms.



8. **Construct** a table like the one shown to summarise what you know about metals and non-metals.

Property	Metals	Non-metals
Conduct electricity well		
Conduct heat well		
Surface features		
State at room temperature		
Malleable		
Ductile		
Brittle		

9. Answer the following questions.
   a. **Identify** the element used inside illuminated signs, such as the one shown.
   b. **Determine** the group in the periodic table to which this element belongs.

10. **Identify** which of the elements iron, lead, hydrogen, oxygen, silicon, uranium, sodium and zinc are:
    a. metals
    b. metalloids
    c. non-metals.
11. **Describe** the event that must occur to separate a compound into separate elements.

Apply and analyse

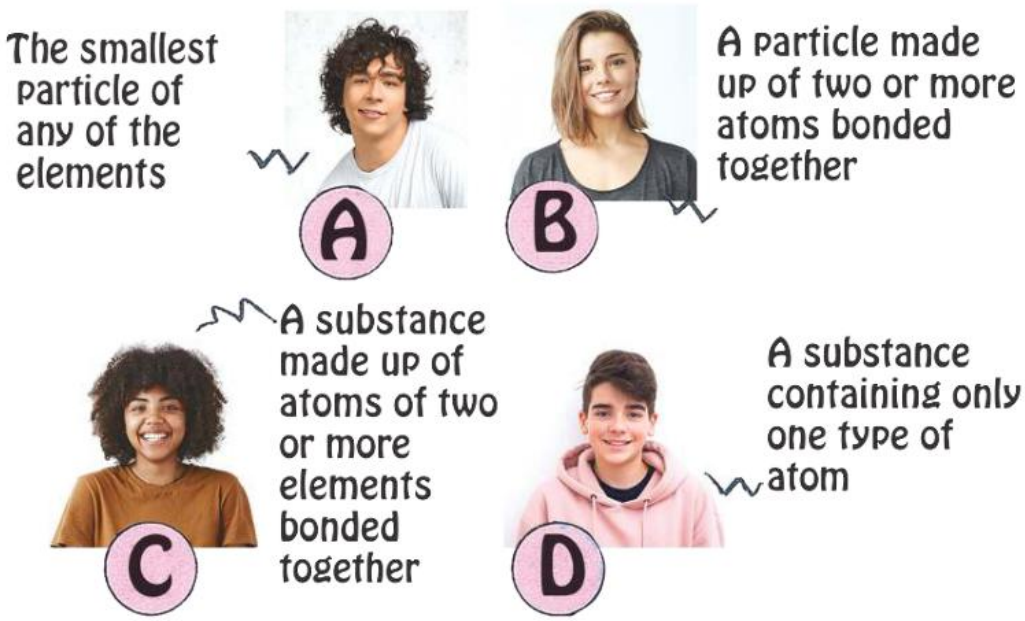
12. MC **Compare** how the molecules in polymers differ from the molecules in other compounds.
    A. They are very small and consist of repeating sub-units or monomers.
    B. They are very large and consist of repeating sub-units or monomers.
    C. They consist of single elements.
    D. They consist of repeating elements.

13. a. **State** whether the substances listed in the table are elements, compounds or mixtures.
b. **Justify** each decision in part a.

Substance	Element, compound or mixture	Why do you think so?
Gold		
Diamond		
Carbon dioxide		
Air		
Seawater		
Pure water		
Iron		
Ammonia		
Table salt (NaCl)		

14. MC **Explain** why water does not appear in the periodic table.
A. Water is a different kind of element.
B. Water cannot be classified into the groups.
C. Water is a compound.
D. Water is naturally occurring.

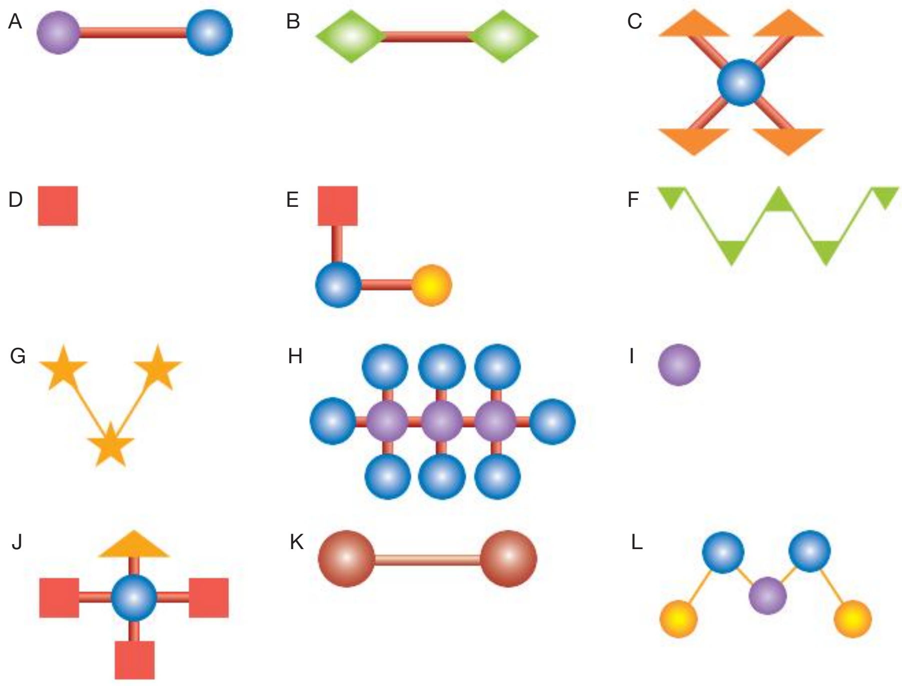
15. Consider each of the comments below and identify whether the person is thinking of an atom, element, compound or molecule.



16. **Identify** what diamonds, the 'lead' in pencils, and coal have in common.
17. **Explain** why, unlike compounds, mixtures cannot be represented by chemical formulas.
18. **Discuss** how Democritus's idea about substances being made up of small particles is similar to the current scientific model. Suggest reasons why most thinkers of his time disagreed with Democritus's ideas.

Evaluate and create

19. Each of the diagrams shown represents one type of substance.



Which of the diagrams represents:

a. an atom of an element

b. a molecule of an element

c. a molecule of a compound?

20. Most of the substances around you are compounds and mixtures.

a. **Describe** the observable differences between a mixture of hydrogen and oxygen and a compound of hydrogen and oxygen.

b. **Explain** the difference between a compound and a mixture in your own words.

21. Respiration is a chemical reaction in which carbon dioxide is produced.

a. **Identify** where respiration occurs in your body.

b. **Identify** what is released during respiration, apart from carbon dioxide.

c. **Suggest** how the carbon atoms in carbon dioxide enter your body.

Answers and sample responses are available in your digital formats.

on To test your understanding and knowledge of this topic, go to your learnON title at www.jacplus.com.au and complete the **post-test**.

5 Chemical change

CONTENT DESCRIPTION

Physical changes can be distinguished from chemical changes, a chemical change can be identified by colour change, a temperature change, the production of a gas (including laboratory preparation and testing of oxygen, carbon dioxide and hydrogen gases) or the formation of a precipitate (VC2S8U08)

Source: Victorian Curriculum F–10 Version 2.0

LESSON SEQUENCE

LESSON 5.1 Overview

5.1.1 Introduction

Chemical reactions are happening all the time, everywhere — even in your body. Within your body, chemical reactions digest food, decay your teeth, use oxygen to convert sugar to energy, convert excess energy to fats, make enzymes and much more. Chemical reactions occur in batteries to provide electricity; in the oven when you bake a cake; in your hair when it is bleached or coloured; and in your car when it burns fuel.

In this topic, you will investigate the difference between physical and chemical changes. Consider the image on the opening page of this topic. Sucrose is being heated, which produces caramel and steam. Do you think this is a **chemical change** or a **physical change**?

FIGURE 5.1 Explosions are very fast chemical reactions. What signs of chemical change are noticeable in an explosion?

DISCUSSION

1. Why does a half-eaten apple go brown?
2. How is an explosion different from other chemical reactions?
3. What makes a nail rust?
4. Why is the Sydney Harbour Bridge continually being painted?
5. What is a backdraught and what causes it?
6. What makes Lycra® so special?
7. Why is recycling so important?

SCIENCE INQUIRY: What is a chemical reaction?

Chemical reactions occur all around you every day. For example, there are thousands of chemical reactions occurring in your body every second, allowing you to breathe, digest and survive.

There are many different types of chemical reactions. Some are easy to see, such as colour changes, but others are not easy to detect, such as the production of a gas. To identify whether a chemical reaction has taken place, scientists look for evidence of change. Common signs of a chemical reaction include:

- a change in colour (e.g. a banana turning brown as it ripens)
- the production of a gas (e.g. bubbling when vinegar reacts with baking soda)
- a change in temperature (e.g. the warmth produced by a hand warmer)
- the formation of a precipitate (a solid that forms when two liquids are mixed)
- a change in energy or light emission (e.g. a glow stick emitting light).

Chemical reactions give many signs indicating that a change in chemical structure of the elements, compounds and mixtures has occurred. It is important to know the changes in a chemical reaction and how vital chemical reactions are to our lives.

Look at figures 5.2 and 5.3 (or real-world examples, such as mixing vinegar and baking soda or observing rust formation). For each image or scenario, complete the following.

1. Record your observations: Identify any signs of a chemical reaction, such as a colour change, gas production or temperature change.
2. Analyse the data: Compare your observations to the list of common signs of chemical reactions. Are there any patterns or relationships between the signs and the reaction occurring?
3. Identify anomalies: If an expected sign of a reaction does not occur, consider why. For example, could the reaction require heat or another condition to proceed?

FIGURE 5.2 A chemical change occurs as this banana ripens and turns brown.

FIGURE 5.3 Runners in long-distance races sweat heavily. Is the loss of water from skin through sweating a chemical reaction?

Information and processed data can be analysed to show patterns, trends and relationships, and to identify anomalies (VC2S8I05)

INVESTIGATION 5.1

Investigating chemical reactions

Aim

To investigate changes that occur during a chemical reaction

Materials

- Space Rocks (popping candy) or Fruit Tingles
- glow stick
- aspirin tablet
- instant ice pack
- plastic cup
- well plate
- bread
- iodine solution
- yeast
- sugar
- conical flask
- water
- balloon

Method

Complete the following tasks and note down your observations.

1. Eat some Space Rocks or Fruit Tingles.
2. Crack a glow stick.
3. Carefully drop an aspirin tablet into a clear cup of water.
4. Hit an instant ice pack.
5. Place a small piece of bread in a well plate. Put two drops of iodine solution onto the bread.
6. Combine a packet of yeast, 100 mL of warm water and 2 tablespoons of sugar in a 50 mL conical flask. Place the neck of a balloon over the top of the flask as quickly as possible.

Results

Reaction	Observations
Space Rocks in your mouth	
Cracking a glow stick	
Aspirin in water	
Hitting an instant ice pack	
Placing iodine on bread	
Combining yeast, water and sugar	

Discussion

1. Explain why each of these reactions is classed as a chemical reaction.
2. Name three signs that a chemical reaction has occurred.
3. Melting an ice cube is classed as a physical change instead of a chemical change. Explain why you think this might be the case.
4. Name three other examples of chemical reactions.

Conclusion

Write a conclusion for this investigation. Your conclusion should state what you discovered about chemical reactions from this investigation.

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Pre-test	Topic 5 Pre-test
eWorkbooks	Topic 5 eWorkbook Student learning matrix
Practical investigation eLogbook	Topic 5 Practical investigation eLogbook
Digital document	Key terms glossary

LESSON 5.2 Physical and chemical changes

LEARNING INTENTION

In this lesson you will identify the difference between chemical and physical changes, and how these can be described using word equations.

5.2.1 Physical and chemical properties

Thousands and thousands of different substances are used in the objects that surround you. All objects are made up of matter. Matter cannot be created nor destroyed. Matter has both physical and chemical properties. Each substance shown in figure 5.4 has physical properties that make it useful for a particular purpose.

Physical properties are those that you can observe using one or more of your five senses — seeing, hearing, touching, smelling and tasting — or by measuring directly. Examples include colour, size, shape, texture, temperature, **malleability** and **ductility**, but there are many, many more.

Some examples in your classroom include the following.

- Plastic tape is transparent and has glue applied to one side only.
- The metal from a spiral binding notebook has been drawn into a wire — it is **ductile** and has also been bent (**malleable**).
- The glass in a pair of reading glasses is solid, hard and transparent.
- The blade on a sharpener is hard so it stays sharp and does not bend.
- Wood from pencils is light, strong and can be shaved using a sharpener.
- The property that makes rubber useful is its **elasticity**. This property is also useful for car and bicycle tyres.

FIGURE 5.4 The objects around you are made of different substances that make those objects useful for a particular purpose.

Chemical properties are those that describe how a substance combines with other substances to form new chemicals, or how a substance breaks up into two or more different substances. Examples of chemical properties include **flammability**, **reactivity** and **toxicity**.

- Flammability refers to how easily a substance catches fire. When a substance burns, it creates new substances.
- Reactivity refers to how easily a substance combines with other substances to produce new substances.
- Toxicity refers to the damage caused to an organism when environmental or ingested substances combine with chemicals in its body and produce new substances that their immune system identifies as toxic. Toxic or foreign substances are always used and broken down in your body first. These chemicals can have damaging, short- or long-term effects on your body.

KEY IDEA

Physical properties can be observed or measured using your senses. Chemical properties describe how a substance interacts with other substances or transforms into new chemicals.

CASE STUDY: What are potato-chip bags made from?

Potato chips are delicious, but to make sure they stay that way they are encased in complex packaging made of several layers. The packaging must be strong because it will need to be handled, but it also needs to be easy enough to open. The inner layer next to the potato chips is usually a polymer called polypropylene, which locks oil in and also keeps moisture and gases, which can spoil the chips, out. Next is a layer of low-density polyethylene (LDPE), another polymer, which gives some strength to the packaging. This is then coated with another layer of polypropylene. Finally, on the outside is a layer of thermoplastic resin that can be printed onto and coloured.

FIGURE 5.5 Why are potato-chip bags pumped full of air? Why is foil often used for the packaging? Could a different material be used?

Some manufacturers are experimenting with compostable packaging that has a layer of polylactic acid polymer; but there is one drawback — these packages are much noisier to open than LDPE packaging. You would notice the difference in sound in a quiet movie theatre!

5.2.2 Chemical changes

When you hard-boil an egg, a chemical change takes place. At about 60 °C the egg white and yolk undergo chemical changes that alter their chemical make-up. Bonds between components of the egg are broken and new bonds between particles are formed. Unlike cooling melted chocolate, which brings about a physical change, cooling the egg will not return it back to its raw state. Most chemical changes are irreversible.

When paper is burnt, it combines with oxygen to form ash (carbon) and smoke (water vapour and potentially other gases, such as carbon dioxide and carbon monoxide). This is a chemical reaction, because new substances are formed. Burning gas in a Bunsen burner is also a chemical change. The methane gas reacts with oxygen in the air to form two new substances: carbon dioxide and water vapour. During this chemical reaction, heat is also produced.

FIGURE 5.6 Cooling a boiled egg will not change it back to its raw state.

How does a candle burn?

When you heat a piece of solid wax, it melts, but does not burn. If solid wax doesn't burn, how does a candle burn? It is the wick in the middle of the candle that burns.

When you light the wick of a candle, the wax at the top of the candle melts. The molten (melted) wax is drawn up the wick just as water soaks into a paper towel. As the liquid wax flows up the wick and gets closer to the heat of the flame it **evaporates** (becomes a vapour). The wax vapour then mixes with oxygen in the air and burns.

FIGURE 5.7 a. When a glass covers a burning candle, it keeps burning until all the oxygen inside is used up. **b.** Once the oxygen is gone, the flame goes out.

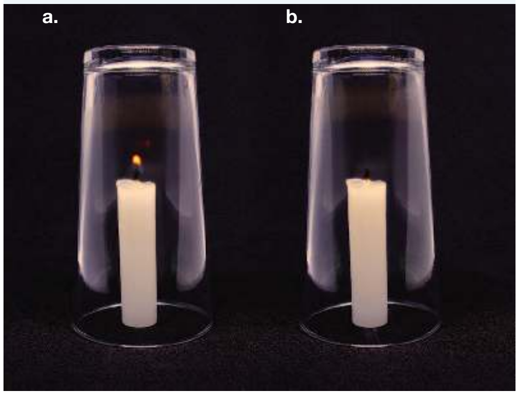


FIGURE 5.8 The physical and chemical changes that occur when a candle burns

INVESTIGATION 5.2

A burning candle

Aim

To observe and describe the changes that take place when a candle burns

Materials

- safety glasses
- candle
- jar lid
- matches
- heatproof mat

Method

1. Place a jar lid on a heatproof mat.
2. Light a candle and allow a drop of wax to drip onto the lid. Place the candle on the drop of wax and fix it to the lid.

Results

1. Observe the candle and write down as many observations of the burning candle as you can.
2. Discuss your observations with others in your group.
3. Blow out your candle and you will see a white vapour rising from the top of the wick.

CAUTION: Do not smell the vapour directly. Fan the odour to your nose with your hand.

To confirm that the white vapour is not smoke, carry out the following test:

Relight the candle. Once it is burning properly, blow it out. Quickly light the top of the vapour trail. The flame should run down the vapour to the wick and relight the candle.

Discussion

1. How far is the flame from the solid wax?
2. The solid wax forms a little pool of liquid wax around the wick. Explain why this happens.
3. Describe the odour of the vapour that is present after the candle is blown out.
4. Draw a diagram of a candle and its flame. Label this diagram to explain how a candle burns.
5. Explain why lighting the wax vapour causes the candle to relight.
6. Which of the observations you have made show evidence of chemical changes?

Conclusion

Summarise the findings of the experiment in three or four sentences.

5.2.3 Physical changes

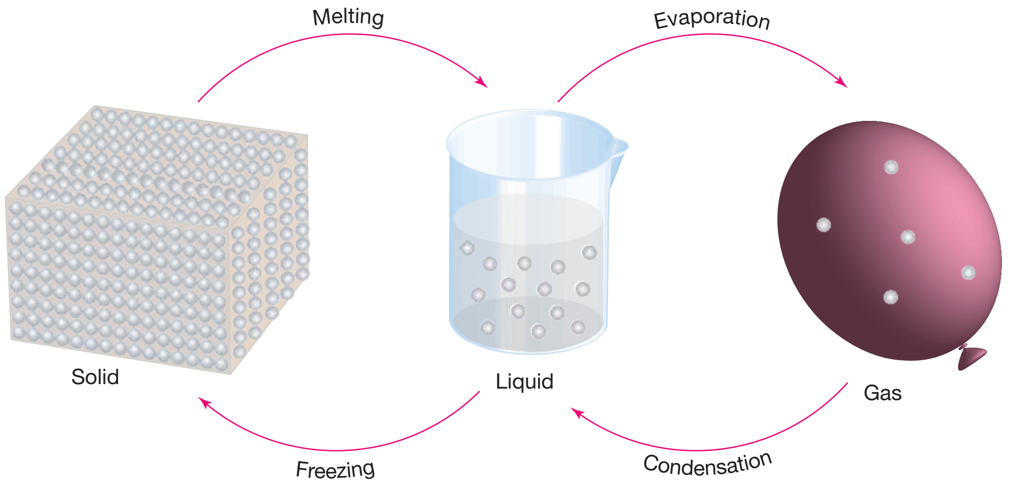
If you enjoy eating chocolate, you will know that it melts on a hot summer's day. This occurs because heat energy from the hot environment is transferred to the chocolate, causing it to melt. The chocolate changes from a solid **state** to a molten state. This means that it is no longer a solid, but it is not (by scientific definition) a true liquid. This change in state is reversible. If the temperature is reduced, the chocolate will solidify again.

FIGURE 5.9 Chocolate in **a.** solid and **b.** molten state

a. b.

These changes to the chocolate are physical changes. Melting, evaporation, condensation and freezing are all physical changes. Changes of state involve either the absorption or release of heat, and are reversible physical changes.

FIGURE 5.10 Changes of state are reversible, physical changes.



Changes in the shape or size of a substance can be physical or chemical changes. These changes are not always reversible. For example, if you drop an egg and it breaks, its shape is changed forever. But when you stretch an elastic band, it can quickly return to its original shape when you let it go.

A physical change does not break any bonds between the atoms of a substance, nor does it create any new bonds. No new substances are formed. However, in a chemical change, bonds are broken and new bonds are formed. New substances are formed and, in general, the reaction is irreversible.

FIGURE 5.11 When water is added to dried copper sulfate, it turns blue. But has a chemical reaction taken place? No reaction has occurred since the solid turns white again when dried.

KEY IDEA

- In a physical change, no new substances are formed. Such a change is often easy to reverse.
- In a chemical change, new substances are always formed. Such a change is often difficult to reverse.

5.2.4 Word equations

When a candle is burned, there are both physical and chemical changes. The melting of the solid wax forms liquid wax, and evaporation of liquid wax forms wax vapour. These are physical changes. The burning of the wax vapour is a chemical change. The wax vapour reacts with oxygen in the air to form new substances, including carbon dioxide and water.

KEY IDEA

Physical and chemical changes can be described using word equations.

- *Physical change:* Melting chocolate can be described by the equation:

  solid chocolate → liquid chocolate

  This equation is reversible by decreasing the temperature:

  liquid chocolate → solid chocolate

- *Chemical change:* The burning of paper can be described by the equation:

  paper + oxygen → carbon dioxide and water vapour

  This equation cannot be reversed.

5.2 Activities

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5.2 Quick quiz on | 5.2 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 5, 6, 10	3, 7, 8, 12	4, 9, 11, 13

Remember and understand

1. MC What does being ductile mean for a metal?
   A. It can be stretched into wires.
   B. It can conduct electricity.
   C. It can absorb heat.
   D. It is transparent.
2. MC What does being malleable mean for a metal?
   A. It is strong and can be shaved.
   B. It is transparent.
   C. It can be moulded into different shapes without breaking.
   D. It can dissolve in water.
3. MC **Identify** from the following options two physical properties that you can describe using your sense of touch.
   A. Texture B. Density C. Colour D. Solubility
4. Flammability, reactivity and toxicity are three examples of chemical properties. Can you think of another one? **Explain** the chemical property you chose, using an example.
5. MC **Identify** the statement that describes the difference between a physical and a chemical change.
   A. During a chemical change, no bonds are broken.
   B. During a physical change, bonds are broken.
   C. During a chemical change, bonds are broken.
   D. During a physical change, the reactants do not change.

6. **Describe** two examples of a physical change.
7. **Describe** two examples of a chemical change.
8. Match the change of state with the physical change.

Change of state	Physical change
a. Change from solid to liquid	A. Freezing
b. Change from gas to liquid	B. Melting
c. Change from liquid to solid	C. Condensation
d. Change from liquid to gas	D. Evaporation

Apply and analyse

9. Consider potato-chip packaging.
   a. **List** the properties of potato-chip packaging.
   b. **Compare** these properties to the plastic packaging used for bags of lollies.
   c. **Explain** why plastic is used for lollies.
10. Imagine that you are designing a spacecraft that will take astronauts to the Moon and back. **List** the properties that the outer surface of the spacecraft would need to have. Include at least two chemical properties.
11. SI Consider the observations in the following table. Complete the table by classifying whether the observation is a physical or a chemical change.

Observation	Physical change	Chemical change
Water freezing to form snow		
A cake baking		
Lighting the gas on the stove		
Petrol evaporating at the petrol pump		
Lighting a match		
Steam condensing on the bathroom mirror		
Melting gold to cast gold bars		
Dynamite exploding		
Bleaching a stain		
Dissolving eggshell in ethanoic acid		

12. SI Sort the following list so that the first step is at the top to describe the chemical change that takes place when methane burns in a Bunsen burner.
    - Carbon dioxide and water vapour produced
    - Methane enters the burner
    - Methane mixes with air
    - Methane burns in oxygen

Evaluate and create

13. SI **Construct** a labelled scientific diagram of a burning piece of wood, showing both the chemical and physical changes occurring.

Answers and sample responses are available in your digital formats.

LESSON 5.3 Chemical reactions

LEARNING INTENTION

In this lesson you will:
- recognise that chemical reactions begin with reactants, which are changed into products
- write word equations for chemical reactions.

5.3.1 Chemical reaction

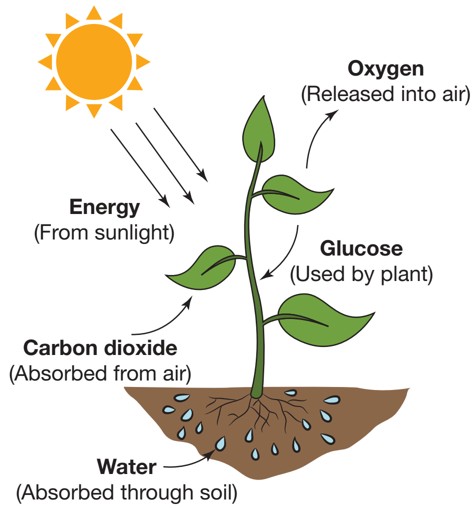
A chemical reaction is a chemical change in which a completely new substance or substances are produced.

Almost all the products you use or wear each day are made by chemical reactions. Examples include cosmetics, concrete, plastics, paper, glass, graphite, stainless steel, shampoo, fibres, food additives, margarine, medicines and many, many more.

5.3.2 Food and chemical reactions

A cheese-and-lettuce sandwich is an incredible mixture of chemicals. Every part of it has been produced by chemical reactions. The most important chemical reaction in growing lettuce is photosynthesis, in which the reactants are carbon dioxide and water. The products are glucose (a type of sugar) and oxygen. This chemical reaction cannot take place without sunlight and a chemical called **chlorophyll**, which gives plants their green colour. In fact, none of the other components of the sandwich could be grown or produced without photosynthesis.

FIGURE 5.12 Photosynthesis is the process by which plants convert light energy into chemical energy.

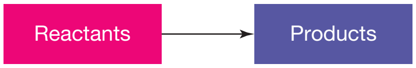


The substance used to make cheese involves a chemical reaction in which a protein in cow's milk called casein reacts with ethanoic acid when heated. Ethanoic acid is found in orange and lemon juice and is more commonly known as acetic acid or vinegar.

5.3.3 Reactants and products

The substances that you begin with in a chemical reaction are called the **reactants**; the substances that are produced are called the **products**. When you wash the dishes, a chemical reaction occurs between the detergent and the mess on the dishes. When you shampoo your hair, some of the chemicals in the shampoo react with the substances on your scalp that contain dust, dirt and bacteria that can make your hair unhealthy.

FIGURE 5.13 In a chemical reaction, reactants are substances that change into products.



KEY IDEA

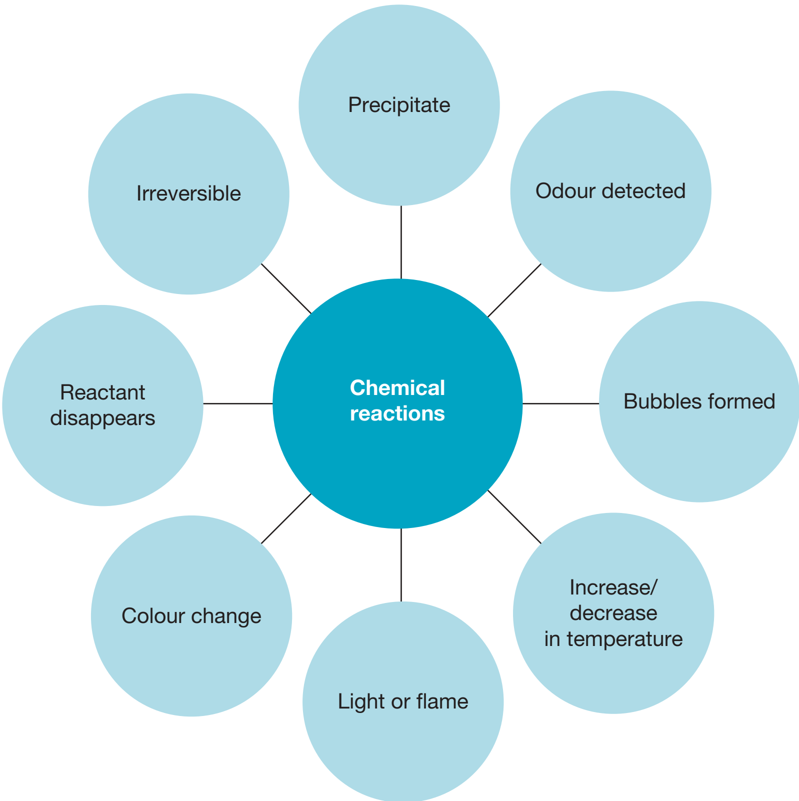
The word 'product' comes from the Latin word *productum*, meaning 'thing produced'.

Where's the evidence?

You can usually tell whether a chemical reaction has taken place by identifying one or more of these clues:

- A **precipitate** is produced. A precipitate is a solid substance, which may or may not be of the same colour as the original mixture. Sometimes this is seen as sediment at the bottom of the reaction flask, or the reaction flask may look cloudy, which is indicative of tiny solid particles having formed.
- An odour is detected.
- Bubbles appear.
- There is an increase or decrease in temperature.
- Light is emitted or a flame appears.
- There is a change in colour.
- A reactant 'disappears'.
- You cannot reverse the reaction and get back to the reactants.

FIGURE 5.14 Ways to identify that a chemical reaction has occurred



However, the only way to be certain that a chemical reaction has taken place is to identify if any new substances (products) have been formed.

5.3.4 Chemical reaction experiments

Before you start each of the following three investigations, design a suitable table for recording your observations.

As you perform the experiments:
1. make a note of the appearance of each of the reactants you start with
2. carry out the experiment and observe carefully to detect any changes that occur
3. describe the changes that take place and the products of the reaction.

INVESTIGATION 5.3

Heating copper carbonate

Aim

To observe and record the chemical reaction that occurs when copper carbonate is heated

Materials

- Bunsen burner, heatproof mat and matches
- safety glasses
- test tube, test-tube rack and test-tube holder
- spatula
- copper carbonate powder

Method

1. Add two spatulas of copper carbonate into the test tube.
2. Using the test-tube holder, heat the test tube in the blue Bunsen burner flame. Remember to move the test tube in and out of the flame and point it away from people.
3. Stop heating when an obvious change has occurred to the copper carbonate.

Results

Record your observations.

Discussion

Describe which observation provides evidence that a chemical reaction has taken place. Explain your reasoning.

Conclusion

Summarise the findings of the experiment in three or four sentences.

Extension

Light a match over the mouth of the test tube once you have stopped heating the copper carbonate. Observe and record what happens to the flame. A gas has been produced in this reaction; suggest what this gas could be and explain your reasoning.

INVESTIGATION 5.4

Magnesium metal in hydrochloric acid

Aim

To observe and describe the chemical reaction between magnesium metal and hydrochloric acid

Materials

- heatproof mat
- safety glasses
- test tube and test-tube rack
- 1-cm piece of magnesium ribbon
- dropping bottle of 0.5-M hydrochloric acid

Method

1. Put the magnesium into the test tube. Place the test tube in the test-tube rack.
2. Add 20 drops of hydrochloric acid to the test tube.

CAUTION: The test tube may become quite hot.

Results

Record your observations.

Discussion

Describe which observation provides evidence that a chemical reaction has taken place. Explain your reasoning.

Conclusion

Summarise the findings of the experiment in three or four sentences.

INVESTIGATION 5.5

Steel wool in copper sulfate solution

Aim

To observe and record the chemical reaction between steel wool and copper sulfate

Materials

- heatproof mat
- safety glasses
- test tube and test-tube rack
- glass stirring rod
- 1-cm ball of steel wool
- dropping bottle of 0.5-M copper sulfate solution

Method

1. Put the steel wool in the test tube. Using the glass stirring rod, push it gently to the bottom of the test tube.
2. Add copper sulfate solution to the test tube to a depth of 2 cm.

Results

Record your observations.

Discussion

Describe which observation provides evidence that a chemical reaction has taken place. Explain your reasoning.

Conclusion

Summarise the findings of the experiment in three or four sentences.

5.3.5 Writing word equations

Each of the chemical reactions in investigations 5.3 to 5.5 can be described by a chemical word equation. In each case the reactants are on the left-hand side of the equation and the products are on the right-hand side.

1. Heating copper carbonate forms copper oxide and carbon dioxide:

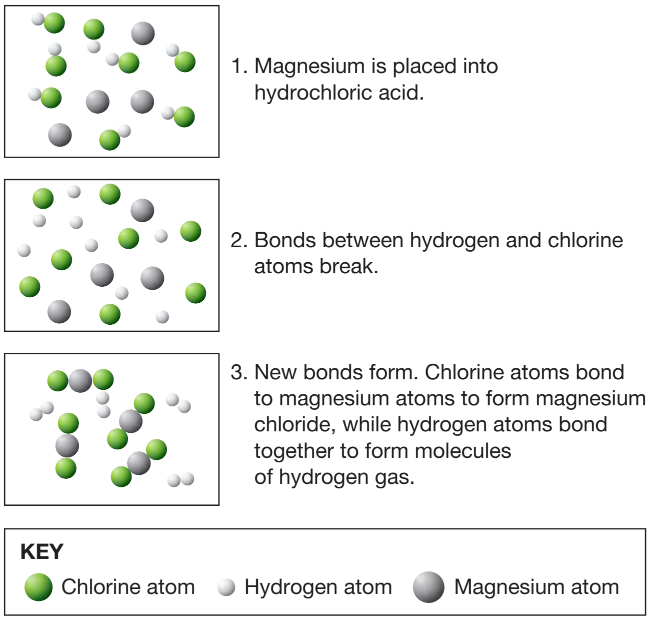
$$\text{copper carbonate} \xrightarrow{\text{heat}} \text{copper oxide} + \text{carbon dioxide}$$

   Although heat is required for this chemical reaction to take place, it is not a substance and therefore is not a reactant. It is written above the arrow for this reason.

2. When magnesium metal reacts with hydrochloric acid, hydrogen gas and magnesium chloride are formed:

$$\text{magnesium} + \text{hydrochloric acid} \longrightarrow \text{hydrogen} + \text{magnesium chloride}$$

FIGURE 5.15 The chemical reaction when magnesium is placed into hydrochloric acid



3. Steel wool (which is made of iron) dissolves in copper sulfate solution to form iron sulfate solution and copper metal:

$$\text{iron} + \text{copper sulfate solution} \longrightarrow \text{iron sulfate solution} + \text{copper}$$

   When writing word equations, it does not matter in which order the reactants are written and the same is true for writing the products. The word equation in the steel wool example above could also be written as:

$$\text{copper sulfate solution} + \text{iron} \longrightarrow \text{copper} + \text{iron sulfate solution}$$

KEY IDEA

- Chemical changes may be summarised using word equations.
- Reactants are listed on the left-hand side of the arrow. Products are listed on the right.

5.3 Activities

learnon

5.3 Quick quiz on	5.3 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 3, 4	2, 5, 7, 8	6, 9, 10

Remember and understand

1. **Identify** which of the following observations provide evidence that a chemical reaction has taken place.

Observation	Is there evidence of a chemical reaction?
a. Change in colour	
b. Heat or light produced	
c. Melting of a substance	
d. Gas produced when boiling a kettle	
e. Stretching a substance	
f. Formation of a precipitate	
g. Gas given off	

2. When magnesium metal reacts with hydrochloric acid, hydrogen gas and magnesium chloride are formed.
   a. **State** the reactants in this reaction.
   b. **State** the products of this reaction.
3. MC **Identify** which of the following is the provided 'real' proof that a chemical reaction has taken place.
   A. Production of a precipitate
   B. Formation of new products
   C. Gas formation
   D. Change in colour
4. Word equations can be very useful to represent chemical reactions.
   a. Fill in the blanks to represent the following reaction as a word equation:
   Octane gas is burnt with oxygen in a car engine to produce carbon dioxide and water.

   ____________ + oxygen gas ⟶ ____________ + water vapour

   b. MC **Identify** which word equation correctly describes the following reaction.
   Sodium metal reacts with chlorine gas to form sodium chloride.
   A. Salt + chlorine gas ⟶ sodium chloride
   B. Sodium gas + chlorine metal ⟶ sodium chloride
   C. Sodium metal + chlorine gas ⟶ sodium chloride
   D. Sodium chloride ⟶ chlorine gas + sodium metal
   c. True or false? The reaction in which hydrogen gas and oxygen gas combine to form water can be described by the following word equation:

   hydrogen gas + oxygen gas ⟶ water

   d. True or false? The reaction in which zinc metal dissolves in hydrochloric acid to form hydrogen gas and zinc chloride can be represented by the following word equation:

   zinc metal + hydrogen gas ⟶ hydrochloric acid solution + zinc chloride solution

5. True or false? The reaction that takes place when copper carbonate is heated is called a precipitation reaction.

Apply and analyse

6. **Explain** why the tomato, cheese, bread and meat in a hamburger cannot be grown or produced without photosynthesis.
7. **Describe** the evidence that one or more chemical reactions take place when meat is grilled.
8. SI Read through investigation 5.4. The method requires a 1 cm piece of magnesium ribbon and 20 drops of hydrochloric acid.
   a. **Describe** how you could tell if the reaction had been completed.
   b. **Explain** how you would know if all the hydrochloric acid had been used up in the reaction.
9. SI **Construct** a diagram (or create a model using an atom modelling kit) to show zinc metal reacting with hydrochloric acid. Remember to add a key to your diagram.

Evaluate and create

10. SI Performing some chemical reactions can be dangerous. Design a safety poster for one of the experiments you have done. Be sure to list all the safety precautions. Your teacher can provide you with the relevant risk assessments for the experiment you have chosen.

Answers and sample responses are available in your digital formats.

LESSON 5.4 Corrosion — a slow chemical change

LEARNING INTENTION

In this lesson you will:
- recognise that corrosion is a reaction in which the chemical and physical properties of metals are changed as they break down, which affects their use
- describe the processes of surface protection and galvanising to prevent corrosion.

5.4.1 Rusting and corrosion

Rusting is an example of **corrosion**. Corrosion is a chemical reaction that occurs when substances in the air or water around a metal 'eat away' the metal and cause it to deteriorate.

There are many examples of corrosion: silver tarnish; the green film that forms on copper or brass objects; and the most common one, the rusting of iron. Corrosion causes enormous damage to buildings, bridges, ships, railway tracks and cars.

5.4.2 Rust

Rust is the flaky substance that forms when iron corrodes. Iron reacts with water and oxygen in the air to form iron oxide and other iron compounds that make up the familiar red-brown substance known as rust.

KEY IDEA

Rusting is a slow chemical reaction that can be represented by the following word equation:

$$\text{iron} + \text{water} + \text{oxygen} \longrightarrow \text{rust}$$

Even strong buildings and bridges that are made from steel, an alloy of iron, are weakened by rusting. The Sydney Harbour Bridge, for example, is continually painted to protect it from moisture and the air, which would cause its steel girders to rust. Ships and cars are also constructed largely of steel. Despite the strength of steel, it needs to be protected from the corrosive effects of the environment.

FIGURE 5.16 The Sydney Harbour Bridge is continually painted to protect it from moisture and the air, which would cause its steel girders to rust.

INVESTIGATION 5.6

Observing rusting

Steel wool is made from iron. You can observe rusting of the iron in steel wool by performing the following experiment.

Aim

To observe and describe the rusting of steel wool

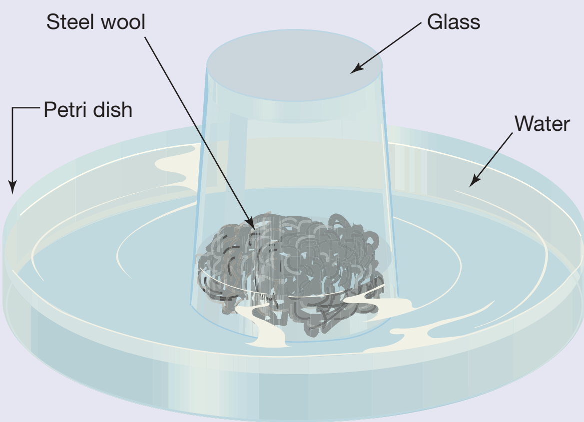
Materials

- Petri dish
- water
- steel wool (without any soap)
- small glass
- permanent marker

Method

1. Pour some water into the Petri dish.
2. Place the steel wool in the middle of the Petri dish.
3. Cover the steel wool by placing the glass over it upside-down.
4. Mark the level of the water on the outside of the glass with a permanent marker.
5. Leave for several days, adding water as required to keep the level at the mark on the glass.

Observing the rusting of iron



Results

Construct a table to record your observations over several days.

Discussion

1. What did you observe about the level of water inside the glass? Can you explain why this happened?
2. Write down a word equation for the chemical reaction that occurred inside the glass.

Conclusion

What can you conclude about the rusting of steel wool?

SCIENCE INQUIRY: What are the requirements for rusting?

In small groups, you are to plan an experiment to answer the question: What are the requirements for rusting?

Rusting is a well-known process, and you might have some ideas about what causes it — but are you sure of the reason? In science, we could answer this question by planning and conducting an experiment to gather data that would allow us to answer it. However, we must be careful to plan our investigation properly so that the data generated will allow us to make a useful conclusion.

Start your planning by answering the following questions.

1. What conditions are needed for rusting to occur? (Think about what you already know and any experiments you already have done.)
2. Do all these conditions need to be present or just certain combinations?

Make a list of all the possible combinations of the conditions that you identified in question **1**. These conditions that you have identified would be the **variables** in your experiment.

Another important step in planning is to consider the equipment you will need.

3. Make a list of the equipment you might need and prepare a brief outline of how you might perform such an experiment.

Reproducible investigations to answer questions and test hypotheses can be planned and conducted, including identifying independent, dependent and controlled variables where applicable, stating assumptions, recognising and managing risks, considering ethical issues and following protocols when accessing cultural sites and artefacts on Country and Place (VC2S8I02)

5.4.3 Speeding up rusting

Some substances in the environment make rusting happen much more quickly. One of the most effective of these is salt. Steel dinghies that are used in the ocean rust much faster than those that are used only in fresh water. This is because the salt in the seawater speeds up the reaction between oxygen in the air and the iron in the steel.

Some chemicals released from factories also increase the rate of rusting. A CSIRO study conducted in Melbourne found that rusting rates were high near airports and sewage treatment plants.

Rusting is much slower in dry environments such as deserts, where the rainfall is nearly zero and there is very little water vapour in the air. This can be seen in figure 5.18 where some aircraft are still structurally sound after 20 years in the desert.

FIGURE 5.17 This 4WD utility has rusted more quickly than usual because of its proximity to the sea.

FIGURE 5.18 In the Mojave Desert, unused aircraft are stored out in the open air.

INVESTIGATION 5.7

Investigating the corrosion of different metals

Aim

To investigate the corrosion of a variety of metals

Materials

- small strips of a range of metals such as copper, aluminium, zinc and magnesium
- sandpaper
- other equipment approved by your teacher

Method

Design and carry out an investigation to study the resistance of a selection of different metals to corrosion. Ensure that appropriate variables are controlled. Before commencing, clean the metal strips with sandpaper to ensure that any coatings already caused by corrosion are removed.

Results

Write a report on your investigation that includes your aim, method, results (including a table), discussion and a clear conclusion listing the metals in order of resistance to corrosion, from most resistant to least resistant. Include the answers to the questions below in your discussion.

Discussion

1. Identify the independent and dependent variables in your investigation.
2. Name the variables that you controlled.
3. Suggest how you might be able to improve or speed up the investigation.

Conclusion

What can you conclude about corrosion of different metals?

5.4.4 Rust protection

The layer of rust that forms on an iron object flakes off the metal, allowing air and moisture to get through to the iron below. This causes more rusting to occur and eventually the iron becomes a heap of rust. It is important to protect iron and steel from corrosion, especially if they are part of a bridge or the hull of a ship.

There are several ways to protect iron and steel from rusting. One way is to prevent oxygen or moisture from contacting the metal. This is called **surface protection**. The metal can be protected by coating it with paint, plastic or oil. If the surface protection becomes scratched or worn off, the metal below can be attacked by moisture and oxygen, and rusting will occur. Examine the painted surface of an old car. Wherever the paint has chipped off, you will find that corrosion has occurred and rust can be seen.

FIGURE 5.19 Rust is a serious problem in the use of iron. The rust formed is brittle and flakes off, which allows the rusting to continue deeper and deeper into the metal.

Another way to protect iron from rusting is to coat it with a layer of zinc. This is called **galvanising**. Zinc is a more reactive metal than iron, and in the presence of moisture and oxygen the zinc layer corrodes, leaving the iron unaffected. Many roofing materials and garden sheds are made from galvanised iron. You can also buy galvanised nails.

KEY IDEA

- Rusting alters the properties of iron and weakens it.
- Iron can be protected from rusting by surface protection and galvanising.

INVESTIGATION 5.8

Rusting and salt water

Aim

To investigate the effect of salt water on the rate of rusting

Materials

- test tubes and test-tube rack
- measuring cylinder
- iron nails
- water
- salt (sodium chloride)

Method

1. Design an experiment to test the effect of the saltiness of water on the time taken for an iron nail to rust.
2. Propose a hypothesis.
3. Discuss your experiment design with a partner. You will need to consider which conditions must be kept the same and which condition will be varied.
4. Consider the purpose of a control and set up a control test tube.
5. Write down your method. It should be clear enough for someone else to follow without any help.

Results

Construct a table in which to record your observations over the next few days.

Discussion

1. Describe the effect of salt on the time taken for the nail to rust.
2. Explain the purpose of a control.
3. Was your hypothesis supported?
4. Outline how your results compare with those of others in your class.
5. Write a report of your findings. Include in your report the aim, materials, method, results and conclusion for your investigation.

Conclusion

Does salt water affect the rate of rusting?

5.4.5 Rusting can be useful

Not all rusting is bad. You can buy hand warmers, which are commonly used by skiers and campers, from pharmacies. These packages will produce heat when you shake them. The contents of the packet include powdered iron, water, salt and sawdust. When the packet is shaken vigorously, the iron rusts quickly, which produces heat.

EXTENSION: Corten steel

Sometimes rust can protect the surface of steel. The steel alloy sculpture shown in figure 5.20 is made from Corten steel. It is a specially developed alloy that is designed to rust over a period of weeks or months to build up a dense protective layer of rust. The rust layer is densely packed and does not let air or water through it, so further rusting cannot occur once the protective layer has rusted. As well as in sculptures, this type of steel can be seen used in modern buildings, garden fences and edging.

FIGURE 5.20 A Corten steel sculpture

5.4 Activities

learnon

5.4 Quick quiz (on)	5.4 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 5, 7	2, 3, 8	6, 9, 10

Remember and understand

1. MC **Identify** the statement that describes corrosion.
   A. A physical change in the composition that causes the solid to break down
   B. A chemical reaction with a metal and other substances that causes the metal to deteriorate
   C. A chemical reaction between a fuel and oxygen that produces heat
   D. A chemical reaction with only one reactant that causes the breakdown of a metal
2. MC **Identify** the statement that describes rusting.
   A. A physical change from solid iron to liquid iron
   B. A chemical reaction between iron and carbon dioxide
   C. A physical change from solid iron to gaseous iron
   D. A chemical reaction between iron, water and oxygen that produces rust
3. **State** which of the following substances can be used for surface protection of metals.

Substance	Provides surface protection of metals?
a. Paint	
b. Water	
c. Oil	
d. Oxygen gas	
e. Plastic	

4. **a.** Complete the sentence: Galvanised iron is iron covered with a layer of _______________.
   b. **Explain** why covering car engine parts with a layer of grease stops them from rusting.

Apply and analyse

5. **Explain** how galvanising protects iron from rusting when the zinc coating corrodes more quickly than the iron.
6. **Explain** why the powdered iron inside hand warmers used by skiers and campers rusts much more quickly than an iron nail.
7. **Explain** why rusting occurs faster in coastal regions than in areas further away from the sea.
8. SI If you have access to an old car, survey it carefully and record all its rust spots. If you do not, then carefully observe the rusty vehicle in figure 5.17. Why are some parts of a vehicle more likely to rust?
9. SI Corrosion is found in many places. Survey your school for rust spots. Write a report to summarise your findings.
10. SI Aluminium corrodes quite quickly, yet it is used to make soft-drink cans. Write a hypothesis about why aluminium cans are not corroded by the drinks they store. Make sure that your hypothesis can be scientifically tested.

Evaluate and create

11. **Construct** an experiment to test the effectiveness of different surface protection methods for preventing corrosion. **Identify** the variables, materials and steps needed. **Explain** how you would measure and compare the results.

Answers and sample responses are available in your digital formats.

LESSON 5.5 Combustion — a fast chemical change

LEARNING INTENTION

In this lesson you will identify that one familiar reaction that causes a temperature change is combustion, which is the reaction of fuels with oxygen to produce heat and products that often contain carbon dioxide and water.

5.5.1 The Earth's atmosphere is important

Most people know that the Earth's atmosphere is important. After all, it contains oxygen, and people and animals need to breathe in oxygen to stay alive. However, the atmosphere is important for many other reasons. These include:

- maintaining a comfortable temperature
- preventing temperature extremes
- protecting all forms of life from harmful radiation
- providing carbon dioxide for plants
- distributing water through rainfall and cloud formation; snow and hail could also be included here
- permitting sound; without an atmosphere, the Earth would be silent!

FIGURE 5.21 Earth's atmosphere is essential for life.

It is very important therefore that humans look after the atmosphere. Historically, the planet and its atmosphere have been thought of as being so big that people could never change them. It was thought that large amounts of waste gases could be put into the atmosphere and that the atmosphere was big enough to take it all. It was also thought that what somebody does in one place would not affect anywhere else.

Unfortunately, it is now known that this is not true. The result is that the balance of some gases, especially carbon dioxide, has been changed. There is now evidence that the Earth is becoming warmer and that climate change is occurring. In the future, everyone will need to think much more carefully about how to treat the atmosphere so that global warming does not become dangerous.

Three gases that will be important in the future are:

- Oxygen. This gas will always be needed, not only for life but because it plays a crucial role in so many processes.
- Carbon dioxide. The amount in the atmosphere has increased significantly, mainly due to the burning of fossil fuels.
- Hydrogen. Although hydrogen gas does not occur in the atmosphere, its use as a fuel in the future is very promising. A big advantage of using hydrogen as a fuel instead of fossil fuels is that it burns to produce water vapour rather than carbon dioxide.

INVESTIGATION 5.9

Laboratory preparation of oxygen gas

Aim

To prepare oxygen gas

Materials

- safety glasses
- 250-mL conical flask
- wax taper or wooden splint
- 100-mL measuring cylinder
- spatula
- hydrogen peroxide solution
- manganese dioxide powder

Method

1. Measure about 80 mL of hydrogen peroxide solution and pour it into the flask.
2. Using a spatula, add a small amount of manganese dioxide powder to the flask and observe what happens. Allow the reaction to proceed for a while.
3. Light a wax taper (or splint). Allow it to burn for a little while until the tip is glowing red.
4. Blow out the flame but make sure the tip is still glowing.
5. Carefully lower the glowing tip into the flask and observe what happens.

Results

Record your observations for steps 2 and 5.

Discussion

1. What is the evidence that a chemical change has occurred?
2. Explain how the glowing splint test proves that the gas in the flask is oxygen.

Conclusion

Summarise your findings for how oxygen can be prepared and identified.

Extension

Research other methods for preparing oxygen safely in the laboratory. What do these methods have in common with the method above?

INVESTIGATION 5.10

Laboratory preparation of carbon dioxide gas

Aim

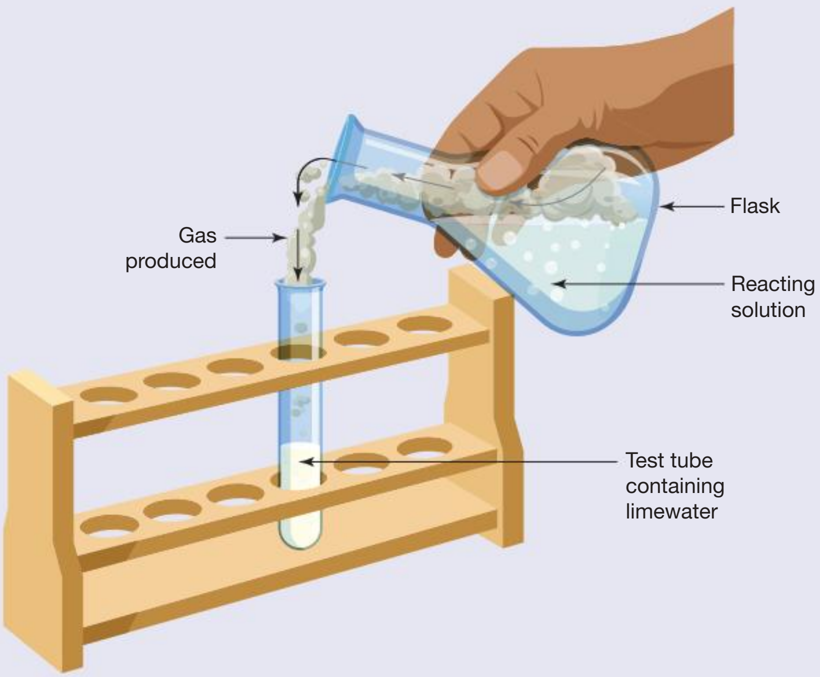
To prepare carbon dioxide gas

Materials

- safety glasses
- 250-mL conical flask
- test tube and rack
- 100-mL beaker
- marble chips
- dilute hydrochloric acid solution
- wax taper (or wooden splint)
- limewater

Method

1. Place some marble chips into the bottom of the flask.
2. Place about 80 mL of hydrochloric acid into the beaker.
3. Add the hydrochloric acid to the flask. Do not add it all at once.
4. Observe what happens. If the reaction appears to be slowing, add some more acid.
5. Light a wax taper (or splint). Once it has been lit, plunge it into the gas collecting in the flask. Observe what happens.
6. Add about a 2-cm depth of limewater to the test tube.
7. As shown in the diagram, now 'pour' the gas from the flask into the test tube containing the limewater. Be careful not to spill any of the reacting solution into the test tube.



8. Gently shake the test tube and observe what happens.

Results

Record your observations for steps 4, 5 and 8 above.

Discussion

1. What evidence is there that a chemical reaction has taken place in step 3?
2. What evidence is there that a chemical reaction has taken place in step 8?

3. What does the ability to pour the gas from the flask into the test tube indicate about the density of carbon dioxide?
4. What does the result with the wax taper (or splint) indicate about carbon dioxide and combustion?

Conclusion

The result from step 7 is the classic test for carbon dioxide. Summarise how carbon dioxide may be prepared and how it is identified.

Extension

If larger amounts of carbon dioxide are required, a Kipp's apparatus may be used. Research how this works. Your school may even have one that you can examine (empty).

INVESTIGATION 5.11

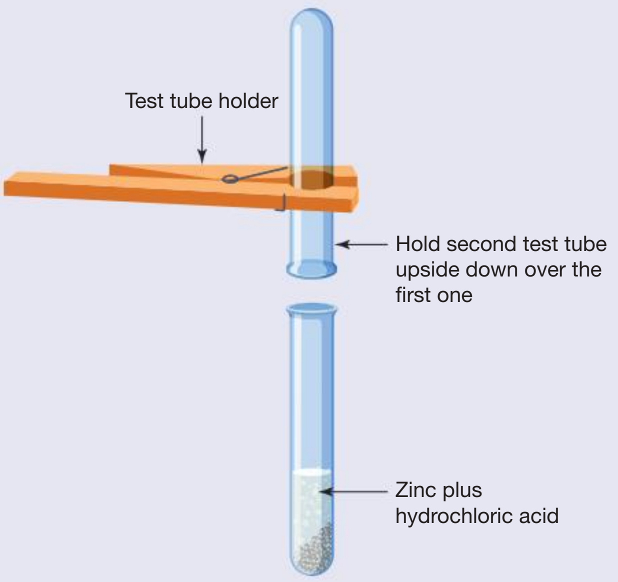
Laboratory preparation of hydrogen gas

Aim

To prepare hydrogen gas

Materials

- safety glasses
- test tube rack
- test tubes
- test tube holder
- matches
- dilute hydrochloric acid
- zinc granules



Method

1. Place some zinc granules in the bottom of a test tube.
2. Add some hydrochloric acid to the same test tube until it is about one-third full.
   Note: the reaction may be slow at first but should gradually speed up.
3. Hold a second test tube upside down over the first as shown in the diagram.
4. Remove the second test tube after a few minutes but keep it upside down.
5. Light a match and bring it to the mouth of the upside-down test tube.

CAUTION: When lighting the match, keep it away from both test tubes until you are ready for this step.

Results

Record your observations.

Discussion

1. What evidence is there that a chemical reaction has taken place?
2. What does the method used to collect the hydrogen indicate about the density of hydrogen gas?
3. Suggest a safety warning for containers that contain hydrogen gas.

Conclusion

The result from step 5 is the classic test for hydrogen. Summarise how hydrogen may be prepared and how it is identified.

5.5.2 Oxidation reactions

Burning is a chemical reaction; it is also known as combustion. It involves the combination of oxygen with a fuel and always produces heat and gases. Reactions that involve combination with oxygen are examples of **oxidation** reactions. One such example is the rusting of iron in the presence of water and oxygen to form iron oxide. There are many other oxidation reactions.

5.5.3 Burning fossil fuels

Burning a **fossil fuel** is a combustion reaction, in which the fuel reacts with oxygen to produce heat, carbon dioxide and water vapour. Fossil fuels are fuels formed from the remains of living things. Petrol, natural gas, coal, wood and even paper are fossil fuels.

The production of carbon dioxide from the burning of fossil fuels is a major source of greenhouse gas emissions, which are a major contributor to climate change.

If the combustion of a fossil fuel occurs when there is not enough oxygen, incomplete combustion occurs. The products are a mix of carbon monoxide, carbon dioxide, solid carbon (soot) and water.

The oxyacetylene torch

To obtain temperatures as high as 3000 °C (hot enough to melt iron and weld metals), acetylene fuel is mixed with pure oxygen in an oxyacetylene torch (figure 5.22).

acetylene + oxygen ⟶ carbon dioxide + water

KEY IDEA

Combustion is a chemical reaction where a fuel combines with oxygen to produce heat and other products. If the fuel is a fossil fuel, these products are often carbon dioxide and water.

FIGURE 5.22 An oxyacetylene torch is used in construction work.

The car engine

Petrol or gas car engines work by the combustion of petrol or gas in the cylinders. A mixture of air and fuel is drawn into each cylinder and ignited by a spark from the spark plug. The fuel reacts rapidly with oxygen in the air. The resulting explosion pushes the piston, which turns the drive shaft. The products of the reaction, carbon dioxide and water vapour, leave the car engine through the exhaust pipe.

EXTENSION: The danger of backdraughts

A backdraught occurs when a fire in a closed room dies down because it has been starved of oxygen, but flammable gases continue to stream out of the hot materials in the room. When a door to the room is opened, air is quickly drawn inside, restoring the supply of oxygen and allowing the fire to reignite. The resulting fire consumes all the flammable gases in a few seconds and produces sufficient heat to ignite any remaining materials in the room. This is very dangerous to firefighters.

Rocket fuels

Liquid and solid fuels are used in the NASA rocket program. When these fuels are burnt, they provide sufficient thrust to place a rocket in orbit hundreds of kilometres from Earth. Liquid hydrogen and liquid oxygen react to power the rocket's main engines. The only product of this reaction is water; it does not produce pollution, unlike the burning of fossil fuels. For this reason, hydrogen is being investigated as an alternative fuel source on Earth.

hydrogen + oxygen ⟶ water

FIGURE 5.23 Oxidation reactions provide the thrust to launch a rocket.

Most of the thrust required to place the rocket in its desired orbit comes from chemical reactions in the solid fuel, which is located in the solid rocket boosters. In space, a liquid fuel such as hydrazine is oxidised to produce an enormous volume of gas. As the gas is released, the rocket is thrust forward. By controlling the direction of the thrust, it is possible to steer the rocket.

SCIENCE AS A HUMAN ENDEAVOUR: How scientific theories can change — the phlogiston theory

Today's theory about how things burn by combining with oxygen has not always been the case. For many years it was believed that combustible substances contained a substance called phlogiston. When a substance burned, this substance was released as fire.

This proved a difficult theory to disprove as it explained many of the observations about fire. For example, if a glass is placed over a burning candle, the candle goes out (see figure 5.8). This was explained by saying that the trapped air in the glass had absorbed as much phlogiston as it could, and there was no room for any more. So the candle went out.

There were, however, some observations that the phlogiston theory could not explain. In 1772, a French chemist called Antoine Lavoisier conducted a number of experiments that showed substances became heavier after they were burnt. According to the phlogiston theory, if something was released from a burning substance, it should be lighter. From this he **postulated** that there was a gas in the air that supported combustion and combined with the material being burnt. He subsequently named this gas oxygen.

FIGURE 5.24 In 1772, Antoine Lavoisier discovered that when objects burn, they combine with oxygen. They do not release phlogiston.

1. Why is it important for scientists to revise or replace theories, like the phlogiston theory, when new evidence contradicts them?
2. How did Antoine Lavoisier's observations and experiments lead to a better understanding of combustion?
3. What does the story of the phlogiston theory teach us about the role of evidence in improving scientific knowledge?

The story of Lavoisier is a good example of how science and politics can be intertwined. Lavoisier was a wealthy man and this enabled him to finance his experiments. At the time, governments did not grant money for scientific pursuits. Unfortunately, the French Revolution took place, and the new rulers despised members of the former rich, upper class. As a result, Lavoisier was guillotined in 1794 at the age of 50.

Scientific knowledge, including models and theories, can change because of new evidence (VC2S8H01)

SCIENCE INQUIRY: The fire triangle

Research the fire triangle. There are many videos online that you might find helpful to do this. You could also look back at figure 5.8.

Answer the following questions.

1. Explain what the fire triangle is.
2. Describe how a fire may be extinguished by reference to the fire triangle.
3. For each of the following situations, identify the leg of the fire triangle that is removed.
   a. The lit wick of a candle is cut and removed with tweezers.
   b. A jar is placed over a lit candle.
   c. A metal spoon is placed very close to a lit candle flame.
   d. Firefighters use water to put out a fire.
   e. A fire break is deliberately burnt in the path of a bushfire.
   f. A carbon dioxide fire extinguisher is used to put out a fire.

Imagine that you are going to visit a class in the primary school that you attended and give a lesson on the fire triangle and how to put out fires. You will need to have some simple demonstrations to show them as you give your talk.

Some simple things that you might use are shown in figure 5.8. You might also like to have a metal spoon, a pair of scissors and any other common articles that are easy to obtain.

Outline your proposed lesson. You might even be given a chance to practise it in front of your class or even go to your previous school and present it!

Communicating ideas, findings and arguments for specific purposes and audiences involves the selection and use of appropriate presentation formats, scientific vocabulary, models and other representations, and may include the use of digital tools (VC2S8I08)

5.5 Activities

learnon

5.5 Quick quiz on	5.5 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 3, 5, 6	2, 4, 7, 8	9, 10, 11, 12

Remember and understand

1. MC **Identify** the statement that describes what burning means.
   A. A physical change that produces a gas by evaporation
   B. A chemical reaction between a fuel and carbon dioxide that produces heat and gases
   C. A chemical reaction between a fuel and oxygen that produces heat and gases
   D. A chemical reaction between a fuel and heat that produces gases
   E. A physical change in which heat is applied to produce gases
2. **Identify** which of the following are evidence that burning is a chemical reaction.

Evidence	Evidence of chemical reaction?
a. Change of state	
b. Release of heat	
c. There are only two products	
d. Production of gases	
e. Bubbles are produced	

3. What is a fossil fuel? **List** three examples of fossil fuels.
4. a. MC What type of reaction is burning?
   A. Reduction
   B. Corrosion
   C. Oxidation
   D. Neutralisation

   b. Write the word equation for each of the following parts i to iii.
      i. The reaction of acetylene with oxygen to make a flame hot enough to weld metals together

      ____________ + oxygen ⟶ ____________

      ii. The reaction of oxygen and petrol or gas in a car engine that produces a hot gas, which causes the movement of the piston, the drive shaft and the wheels of the car

      ____________ + fuel vapour ⟶ carbon dioxide + water

      iii. Energy is released by the reaction of hydrogen and oxygen that produces the thrust necessary to get rockets into orbit.

      ___________ + ___________ ⟶ water

5. Is rusting an example of burning? **Explain** your response.
6. Select the correct substances to complete the word equation.

   fossil fuel + ____________ ⟶ ____________ + water vapour

7. MC Which of the following are names given to chemical reactions in which fuels react with oxygen? Select all possible answers from the options given.
   A. Burning
   B. Corrosion
   C. Combustion
   D. Oxidation

Apply and analyse

8. Space agency scientists are constantly searching for better rocket fuels. **List** the properties for these fuels that are
   a. desirable
   b. undesirable.

9. **SI** The following table shows the heat of combustion per kilogram of certain fossil fuels.

Fuel	Heat value (MJ per kg)
Methane	50
Petrol	44
Natural gas	42
LPG	46
Diesel fuel	42

a. Use the data in the table to make a bar chart of the fossil fuels.
b. **Identify** which of the fossil fuels in your bar chart produces the most amount of heat per kilogram.
c. **Suggest** why this fossil fuel is not used to power cars in Australia.

Evaluate and create

10. **SI** **Suggest** why in most buildings we have thick fire doors that have to remain closed.
11. A student conducts an experiment in which they burn magnesium in the presence of oxygen. At the end of this experiment, the compound magnesium oxide is produced.
    a. How do you know that a chemical reaction has taken place?
    b. Write a word equation for the chemical reaction.
    c. Would this reaction be classed as a combustion reaction? **Justify** your response.
12. **SI** Read through investigation 5.10.
    a. **Suggest** how you could establish that the limewater did not react with another substance in order to turn milky.
    b. **Construct** an investigation to show that limewater reacts with carbon dioxide to turn a milky colour.

Answers and sample responses are available in your digital formats.

LESSON 5.6 Indicators of chemical change in our everyday world

LEARNING INTENTION

In this lesson you will discuss where indicators of chemical change are used in order to identify the presence of particular substances, such as in soil, water and medical testing kits.

Indicators of chemical change are used for identifying the presence of particular substances, such as in soil, water and medical testing kits.

5.6.1 Test kits

As knowledge of the environment increases, so too does the need to test the land, waterways and air for the safety of everyone and all living things in these habitats. The invention of simple, affordable and easy-to-use test kits has enabled environmental testing to occur quickly and easily. In addition, the development of medical testing kits in response to public demand has resulted in people being more aware of their medical needs, and able to feel more in control of their health. These kits test for a specific chemical or chemicals by the addition of a very small amount of the test substance. A chemical reaction occurs, which shows the presence or absence of the substance being tested for. The kits may show a colour change, or have a line appear that indicates a positive result for the substance being tested.

5.6.2 Indicators of chemical change in soil

FIGURE 5.25 A soil testing kit showing a pH test result

Crop production is a vital industry worldwide to feed our growing population. Farmers are now able to monitor the health of the soil by using simple test kits. Soils that are nutrient poor will result in little to no crop production. Testing the pH of soil involves an easy chemical reaction to perform that provides important information about the health of the soil and what treatment it may need. If soil is too acidic or too basic, crops may not grow. The pH is used as an indicator of the availability of nutrients in the soil. If the pH is less than 6, the soil will be deficient in calcium, magnesium, molybdenum, phosphorus and potassium. If the pH is less than 4, it is most likely that toxic amounts of aluminium and manganese are present in the soil. If the pH is greater than 7, the soil may be deficient in boron, copper, iron, manganese and zinc. These test kits generally show a colour change, with a key that explains the colour produced.

INVESTIGATION 5.12

Examining flower colour under different pH conditions

Aim

To determine the effect of acidic and basic conditions on the colour of the flowers of hydrangea plants

Materials

Two hydrangea plants that have been grown in acidic and basic conditions and are currently flowering

Method

1. Measure and record the pH of the soil of each plant.
2. Record the colour of each plant.

Results

1. Create an appropriate table to tabulate your results and observations.
2. Write a report about your experiment.

Discussion

1. Describe the conditions that led to the various colours of the flowers.
2. What colour would the flowers be if the pH was neutral?

Conclusion

What can you conclude about how pH affects the plant growth and flower colour of hydrangeas?

5.6.3 Indicators of chemical change in water

Measuring the chemical properties of water is a common requirement in many industries. The run-off of water from industrial sites can be tested for the presence of lead, iron, copper, nitrates, chlorine, fluoride, toxins, fertiliser and even microorganisms, using water testing kits. These test kits can also be used to analyse drinking water, ponds, lakes and swimming pools. The result is generally indicated by a colour change on a test strip, with a key to explain the result. Two common tests on swimming pool water are chlorine level and pH.

The pH scale runs from 0 to 14 and measures how acidic or basic a sample is. It has the following features:

- A pH of 7 is neutral (neither acidic or basic)
- pH values less than 7 are acidic. The lower the value, the more acidic a sample is.
- pH values higher than 7 are basic. The higher the value, the more basic a sample is.

FIGURE 5.26 Pool-water test kits can be made up of test strips or a water test with an indicator showing different pH colours or chlorine levels.

KEY IDEA

pH is a measure of how acidic or how basic a sample is.

INVESTIGATION 5.13

Water testing

Aim

To test what chemicals are present in the water of our school environment and its pH

Materials

- water samples from various locations in the school (e.g. a pond, taps in different locations, puddles, rain water, tank water)
- water test kit — either test strips or a liquid test kit
- pH test kit

Method

1. Create a table for the results listing the sites where the water samples were obtained from, the chemicals being tested for and a column for the pH.
2. Following the instructions on the test kits, test each water sample for each chemical component and record your results in your table.

Results

1. Record your results and observations in your table of results.
2. Graph your data on the one graph, using different colours for each water sample.

Discussion

1. Were there any trends in the data that you recorded?
2. Were there any specific chemicals that were present or absent for the majority of the water samples? What does this mean in terms of water quality?
3. Describe how the pH varied across the various water samples. What does this mean in terms of water quality?
4. Can you think of any reasons to explain the results that you obtained for the water samples from the various sites?

Conclusion

What can you conclude about the water quality of the various sources in your school?

EXTENSION: pH meters

Easy-to-use pH meters are now available for testing soil and water. If you have these available, you could use them to check your results.

5.6.4 Indicators of chemical change in medical testing kits

There have been incredible developments in the production of simple and quick medical testing kits over the last decade. All of these kits test for specific chemicals, proteins or hormones. The test substance is added to the kit and a response is observed within a specified time frame. The most significant and broadly used test kits are the rapid antigen tests (RATs) for the presence of the COVID-19 virus.

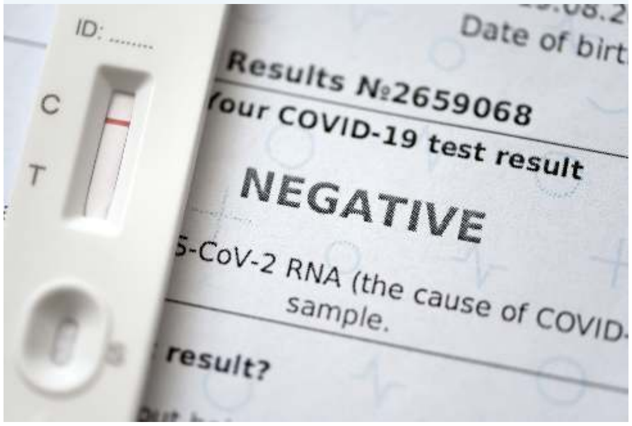
Testing for COVID-19

COVID-19 is a disease caused by the SARS-CoV-2 coronavirus. There are two kinds of tests available for the testing of COVID-19. The tests detect either of the following:

- The presence of the SARS-CoV-2 virus in the body, by testing if the virus is present in the throat, nose, nasal secretions or sputum
- Whether the body is producing antibodies to the SARS-CoV-2 virus, by testing a blood sample.

The two types of tests that detect the presence of specific components of the virus are rapid antigen tests and nucleic acid tests. Rapid antigen self-testing kits have allowed for home testing, where a person can collect the sample, perform the test and interpret results, indicated by lines that appear in the panel.

FIGURE 5.27 A negative SARS-CoV-2 rapid antigen test



EXTENSION: Nucleic acid tests

Nucleic acid tests detect the presence of genetic material of the SARS-CoV-2 virus. The tests available include the polymerase chain reaction (PCR) test and a kit called the loop-mediated isothermal amplification (LAMP) test. These tests are more complicated to complete and are performed by trained scientists in pathology and medical laboratories.

Other medical testing kits

There are numerous medical testing kits available, from the blood alcohol and drug testing kits utilised by police, to home testing kits for ovulation, pregnancy, glucose levels in the blood and urine, and genetic data. Pregnancy tests identify the level of a hormone called human chorionic gonadotropin (HCG) in urine. This hormone is only produced during pregnancy and usually can only be detected after approximately two weeks of pregnancy due to the sensitivity of the test.

Glucose test kits can use urine or blood samples to monitor blood sugar levels. A urine test strip is a very basic test for the presence of glucose. To determine whether a person has diabetes, more testing is required. Once a person has been diagnosed with either type 1 or type 2 diabetes, they must monitor their blood sugar levels regularly. If blood glucose levels get too high or too low, the condition may become life-threatening to the individual. There are many different types of devices available for testing blood glucose levels, with technological developments improving their accuracy and ease of use, progressively.

FIGURE 5.28 Two testing methods for body glucose levels: a. a simple urine testing kit b. a blood testing device

a.

b.

KEY IDEA

Many examples of chemical test kits are available, which make it easy for people to detect important chemical changes.

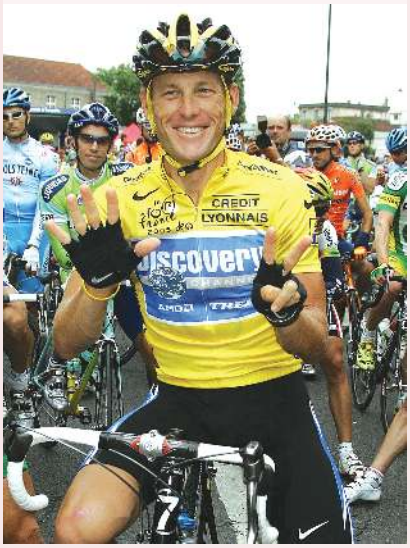
SCIENCE AS A HUMAN ENDEAVOUR: Testing for performance-enhancing drugs in sport

Athletes may accidentally or intentionally ingest banned substances or performance-enhancing drugs that increase their athletic performance. Banned substances include some over-the-counter medicines as well as drugs of abuse. They also include some dietary supplements or foods that are considered to provide an enhancement to athletic performance. Performance-enhancing drugs are illegal substances that provide an unfair advantage to the athlete.

Failed drug tests, resulting from the ingestion of these substances, can end an athlete's career. As a result, performance-enhancing drugs are constantly being developed, produced and modified to avoid detection.

Drugs are metabolised by the human body. Scientists can search for the drug or its products of metabolism when analysing biofluids such as the saliva, blood or urine samples of an athlete. The products of metabolism of drugs can stay in the body's system and bloodstream for many weeks. Biofluids are kept by the relevant sporting authorities for many, many years so that scientists are able to test the samples years later for performance-enhancing drugs. The biggest challenge to the World Anti-Doping Agency in the detection of illicit drugs is the fact that they need to know the composition of the drug that they need to screen for. Scientists can only develop a test for a substance once they know what the substance is. Therefore, sporting authorities are always investigating substances found in biofluids and researching whether they are performance-enhancing drugs or not.

FIGURE 5.29 Lance Armstrong holds up seven fingers signifying his seven Tour de France titles



One of the most famous cases of doping in sport involved American cyclist Lance Armstrong. Armstrong was a successful worldwide cyclist who survived testicular cancer and won the Tour de France seven times (1999 to 2005). He also won a bronze medal at the 2000 Olympic Games. Despite denying doping for years, Armstrong finally admitted to using performance-enhancing drugs in 2013. This confession led to widespread outrage, loss of endorsements, destruction of his reputation and the stripping of his titles and medal. He was described by the United States Anti-Doping Agency as the mastermind of 'the most sophisticated, professionalised and successful doping program in the history of sport'.

1. Why do you think it is important to ban performance-enhancing drugs in sports? Should athletes who use these substances face lifelong consequences, even if they admit their mistakes?
2. Suggest how the use of performance-enhancing drugs affects the fairness and reputation of sports for fans, athletes and society.
3. What are some of the difficulties scientists face when detecting new performance-enhancing drugs, and how can these challenges impact the fight against doping in sports?

Proposed scientific responses to socio-scientific issues impact on society and may involve ethical, environmental, social and economic considerations (VC2S8H03)

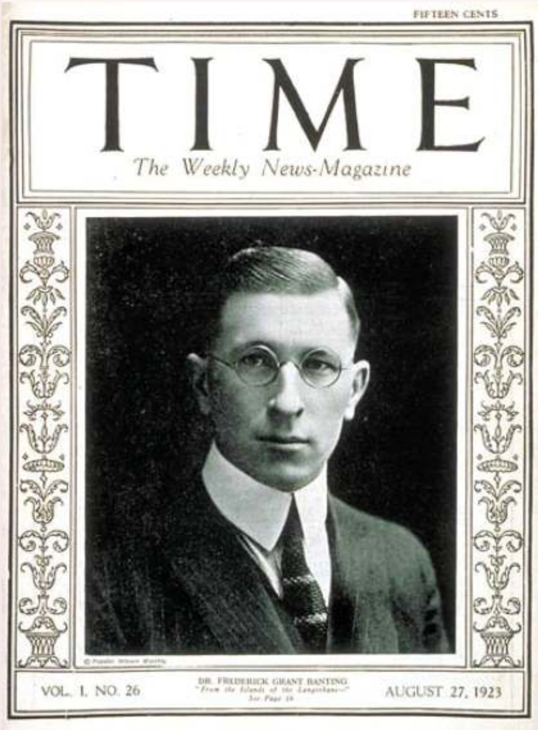
SCIENCE AS A HUMAN ENDEAVOUR: Sir Frederick Banting and the discovery of insulin

Sir Frederick Banting (1891–1941) was a Canadian doctor and medical researcher. He was the leader of the team that discovered and isolated insulin in 1921.

Prior to this time there was no treatment for diabetes and sufferers died a slow and painful death. In early 1922 he was able to inject this isolated insulin into a young boy suffering from this disease. The young boy subsequently improved, and with regular injections, was able to go on and lead an otherwise normal, healthy life. This discovery and treatment has subsequently saved millions of lives worldwide. In 1923, Banting and one of his co-workers were awarded the Nobel Prize in Medicine for this discovery. To this day, Banting remains the youngest person to have received this award for medicine. Banting was killed in a plane crash in 1941 at the age of 49.

It is important to realise that Banting did not work in isolation. Like many famous discoveries in science, he relied upon the previously published works of other scientists, of many nationalities. He also worked in a team, with the various members contributing different ideas and skills to the final result.

FIGURE 5.30 Sir Frederick Banting. Widely credited as the discoverer of insulin.



1. Why is teamwork important in scientific discoveries, such as the discovery of insulin? How might Banting's work have been different if he had worked alone?
2. How does the discovery of insulin illustrate the value of building on the research and ideas of scientists from around the world?
3. What does the discovery of insulin teach us about the importance of sharing knowledge and working collaboratively to solve global health challenges?

Multidisciplinary endeavours to advance scientific knowledge make use of people's different perspectives and worldviews (VC2S8H02)

5.6 Activities

learnon

5.6 Quick quiz	5.6 Exercise

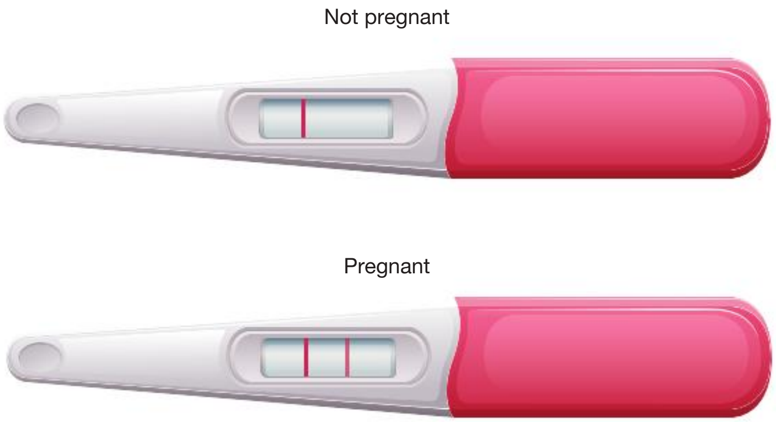
LEVEL 1	LEVEL 2	LEVEL 3
1, 4	2, 5	3, 6

Remember and understand

1. Why do we use chemical test kits in our everyday world?
2. MC Which of the following statements is *incorrect*?
   Chemical test kits can be used to indicate:
   A. the presence of sugar or protein in urine.
   B. very small amounts of chemicals in the soil.
   C. how much chlorine needs to be added to a pool.
   D. the presence of the SARS-CoV-2 virus in your body.
3. **Outline** how chemical test kits work.

Apply and analyse

4. The pH of soil can have a significant effect on plant growth. **Describe** how soil pH affects the flower colour of hydrangea plants.
5. In the following figure, the pregnancy test kit results show one line for a 'not pregnant' result and two lines for a 'pregnant' result. **Suggest** why the 'not pregnant' result shows only one line?



Evaluate and create

6. A new chemical test kit called IntelliGender® has recently been marketed around the world. The product is advertised as a gender verification kit and says that it will turn urine green for a boy or yellow/orange for a girl. The company claims a 90% accuracy rate. However, its website advises against making financial, emotional or family-planning decisions based on the test results, including NOT painting the nursery or buying gender-specific clothing.
   How reliable and useful do you think the IntelliGender® test kit is, considering its claimed accuracy and the company's advice against making decisions based on the results? **Justify** your response.

Answers and sample responses are available in your digital formats.

LESSON 5.7 Plastics and fibres

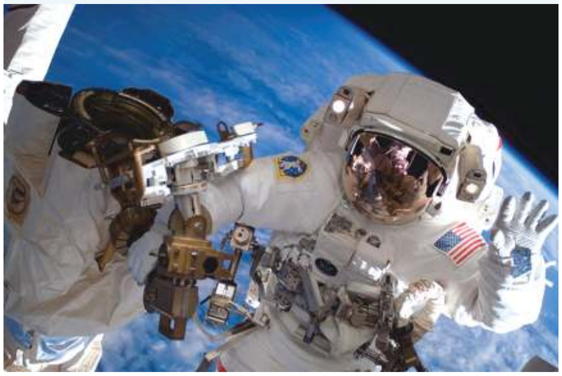
LEARNING INTENTION

In this lesson you will describe examples of how plastics and fibres or their blends can be developed for a particular purpose.

5.7.1 Plastics

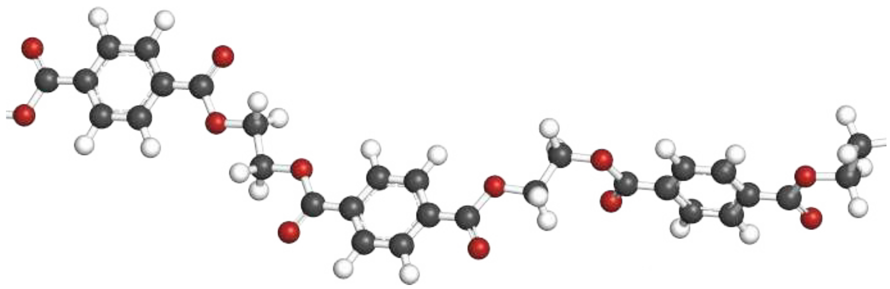
The scientists and engineers who develop new plastics for spacesuits that allow astronauts to walk in space need a knowledge of chemistry to create materials that are strong, light and heat resistant. Developing new materials for a particular purpose requires an assessment of the required properties and an understanding of chemical reactions.

FIGURE 5.31 The spacesuits worn by astronauts when they are walking in space contain many layers of materials developed by scientists and engineers.



Metals, paper and ceramics have been used for thousands of years. But plastics have been around for less than 100 years. Plastics are synthetic (manufactured) materials that can be easily moulded into shape. Some plastics are flexible and soften when they are heated. They can be easily moulded into products such as milk and fruit-juice containers, rubbish bins, spectacle lenses, electrical insulation and laundry baskets. Others are quite hard and rigid. These plastics are used to make items such as toilet seats, electrical switches, bench tops and outdoor furniture. Most plastics are the products of chemical reactions with crude oil — from which petrol and bitumen are also produced — as the main reactant.

FIGURE 5.32 Plastics are made from chains of molecules and are also called polymers.



KEY IDEA

The word 'plastic' comes from the Greek word *plastikos*, meaning 'able to be moulded'.

CASE STUDY: Plastic currency

Australia was the first country in the world to use only plastic notes for currency. The notes are more difficult to forge and last much longer than the old paper notes.

DISCUSSION

Working collaboratively, or independently, make a list of at least ten items in your homes that are made from plastic. Imagine that these could no longer be made from plastic! For each item, think about the most important properties the item must have and discuss which other material could be used to make it.

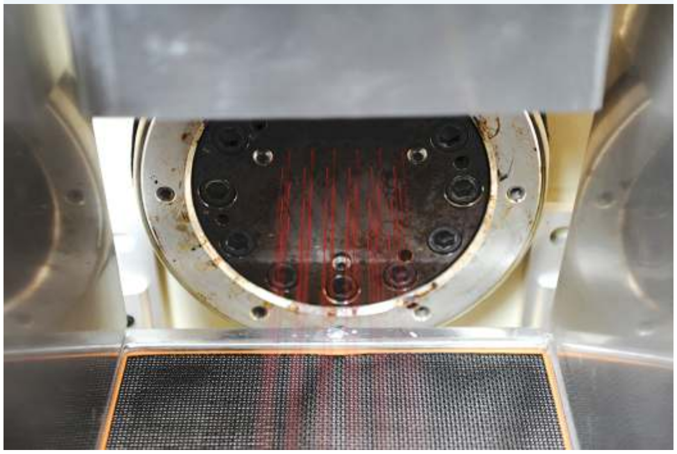
5.7.2 Fibres

Until the development of nylon in 1938, just in time to make parachutes for World War II, the world relied almost completely on fabrics made from **natural fibres**, such as wool, cotton, linen and silk.

Animal-based fibres include wool from sheep and silk from silkworms. Cotton is derived from cotton bushes and linen comes from flax plants. Today, it would be impossible to provide clothing and bedding for the world's population with purely natural fibres because of the amount of land and water that would be needed for crops and sheep.

Synthetic fibres such as those used in compression sports gear have many desirable qualities that natural fibres lack, including easy care, colour-fastness and being lightweight.

FIGURE 5.33 Synthetic fibres form when soft plastic is forced through the holes of a spinneret.

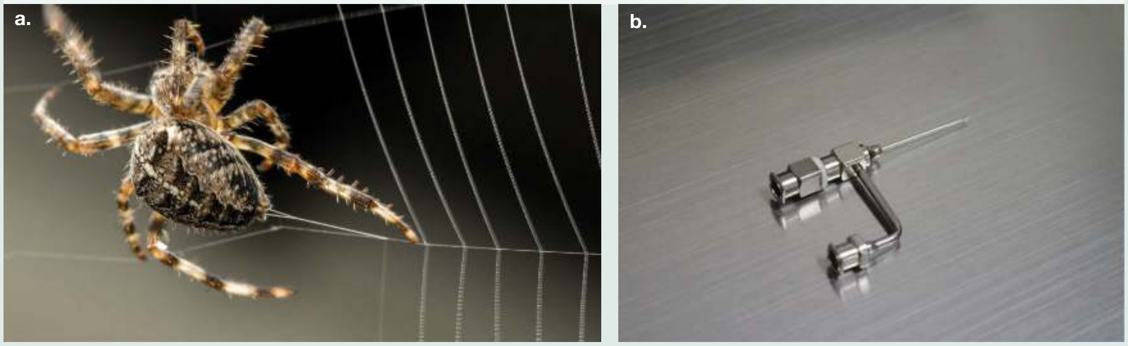


Of the many synthetic fibres, the most widely used are **nylon** and **polyester**. Synthetic fibres are made by pushing softened plastic materials through tiny holes in a nozzle called a **spinneret**, which looks a little like a shower head.

EXTENSION: Biomimicry

Biomimicry is the imitation of designs found in nature to solve human problems using technology. The spinneret used to make synthetic fibres is an example of biomimicry. The spinneret gets its name from the organ used by spiders to spin their webs. Liquid silk flows through the spider's spinneret. It hardens into a fibre as it passes through. Most spiders have six spinnerets.

FIGURE 5.34 The spinneret **a.** on a spider **b.** manufacturing device



KEY IDEA

In a fair test such as the one you will develop in investigation 5.14, it is important to control and measure variables. For a test to be fair, the variables must be controlled. For example, when testing fibre elasticity, all fibres should have the same length and thickness, be attached to the testing frame identically, and experience the same force for the same duration. This ensures accurate comparisons.

INVESTIGATION 5.14

Testing fibres

Aim

To observe and describe the properties of a range of fibres

Materials

- a range of threads of different fibres (e.g. cotton, polyester, wool, nylon, rayon)
- uniformly sized fabric samples made from different fibres or blends of fibres
- equipment decided upon by the group

Method

Work in groups of three or four to complete this investigation.

1. Start by listing the properties of either the fabric samples or the fibres that can be tested by experiments. Some examples to help get you started include flammability, elasticity and the ability to absorb water.

Devise an experiment that will allow you to compare one property of threads of either different fibres or different fabric samples.

2. Make a list of the equipment you will need.
3. Have your experiment plan and equipment list checked by your teacher.

CAUTION: Obtain your teacher's approval before carrying out any tests. Synthetic fibres or blends should be burned only in a fume cupboard.

Results

1. Carry out your experiment and keep a record of your measurements and observations.
2. Write a report about your experiment.

Discussion

1. List the dependent and independent variables.
2. List the variables that you were able to control in your experiment.
3. Identify any variables that were uncontrolled.
4. Identify the most useful properties of each of the fibres or fabrics that you tested.
5. Suggest at least one improvement that you could make to your experiment.

Conclusion

Summarise the findings of the experiment in three or four sentences.

Blends

Many of today's fabrics are made from blends of natural and synthetic fibres to make the best use of the properties of each fabric in the blend. A blend of polyester and cotton is commonly used for shirts and dresses. The cotton helps keep the wearer cool, while the polyester reduces creasing.

Rayon is shiny, easy to dry and cool in summer. On the 'down' side, it has low **durability** and is not **elastic**. Elasticity describes the ability of a material to return to its original size and shape after being stretched. Rayon is neither a natural nor a synthetic fibre. To make it, cellulose fibres from spruce and eucalypt trees are mixed with chemicals that soften them. The mixture is then passed through a spinneret. Rayon is often referred to as a **regenerated fibre**.

Lycra®

When you watch the feats of Olympic athletes, cyclists, skiers and skaters, it is almost certain that they are wearing Lycra®. Lycra is not a fabric; it is the registered trademark of a synthetic fibre called spandex. Spandex was invented in 1958. Spandex is lightweight, durable, retains its shape and fits snugly. It even pulls moisture away from the wearer's skin. Spandex is very elastic. It can be stretched to up to seven times its normal length and spring back to its initial length when released. Spandex is always blended with other fibres. As little as two per cent of this material in a blend makes a difference to the properties of the fabric. Lycra suits usually consist of between three per cent and ten per cent spandex.

Each fibre, whether natural or synthetic, has advantages and disadvantages. Some of these are outlined in table 5.1.

TABLE 5.1 Advantages and disadvantages of fibres

Fibre	Advantages	Disadvantages
Wool	• Warm in cold weather • Crease resistant • Burns slowly • Retains its shape well	• Shrinks when washed • Turns yellow in sunlight
Cotton	• Absorbs moisture • Soft • Cool in hot weather	• Creases easily • Burns quickly
Nylon	• Dries quickly • Light • Strong • Elastic	• Builds up static electricity • Melts rather than burns
Polyester	• Dries quickly • Crease resistant • Resistant to many chemicals	• Builds up static electricity • Melts rather than burns

5.7 Activities

learnon

5.7 Quick quiz on	5.7 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 4	3, 6, 8	5, 7, 9, 10, 11, 12

Remember and understand

1. MC Which single property do all plastics have?
   A. Flexible
   B. Can be moulded
   C. Rigid
   D. Cannot be moulded
2. MC **Identify** the source that all natural fibres come from.
   A. Plants or animals
   B. Plants only
   C. Animals only
   D. Soil
3. **State** the reason cotton and polyester blends are so commonly used for shirts and dresses.
4. **Describe** what a spinneret is used for.

5. **MC** Which fibre does Lycra® clothing always contain?
A. Spandex
B. Nylon
C. Elastane
D. Polyester

Apply and analyse

6. **State** which properties make plastic more suitable for use in outdoor furniture than:
   a. wood
   b. metal.
7. **Identify** which properties of plastic banknotes make them more suitable than the old paper ones.
8. **State** whether each of the following are properties of nylon; if yes, **explain** how the properties contributed to making nylon suitable for use as parachute material in World War II.
   a. Light but strong
   b. Strong and heavy
   c. Shrinks when washed
   d. Elastic
   e. Burns quickly
   f. Waterproof and dries quickly
   g. Builds up static electricity.
9. **Explain** why rayon is neither a natural fibre nor a synthetic fibre.
10. **Describe** how the properties of a pure cotton fabric would change by blending it with spandex.

Evaluate and create

11. **SI** Examine the table provided, which lists some advantages and disadvantages of natural and synthetic fibres.

Fibre	Advantages	Disadvantages
Wool	• Warm in cold weather • Crease resistant • Burns slowly • Retains its shape well	• Shrinks when washed • Turns yellow in sunlight
Cotton	• Absorbs moisture • Soft • Cool in hot weather	• Creases easily • Burns quickly
Nylon	• Dries quickly • Light • Strong • Elastic	• Builds up static electricity • Melts rather than burns • Turns yellow in sunlight

   a. Which of the materials would burn slowly if it were exposed to flames?
   b. **Deduce** one advantage and one disadvantage of synthetic materials over natural materials.
   c. **Deduce** one disadvantage that one natural material and one synthetic material both have in common.
12. **SI** Choose one of the properties in investigation 5.14 (one that you have not investigated) and decide on the equipment you would use to investigate it.

Answers and sample responses are available in your digital formats.

LESSON 5.8 Recycling

LEARNING INTENTION

In this lesson you will:
- identify the types of plastics that are easily recyclable and those that are more difficult
- understand how glass, metal and paper products can be sorted and recycled in a recycling facility.

5.8.1 Why is waste reduction important?

There are many reasons why reducing the amount of waste produced is important. Some of these are listed below.

- To reduce the volume of material going to landfill. The sites for future landfill are becoming harder and harder to find. Also, as cities and towns expand, people do not want to live next to tips.
- To reduce the frequency of transport to landfill. Transport uses fossil fuels and produces greenhouse gases. More recycling means less rubbish and therefore fewer trips.
- To reduce the volume of greenhouse gases produced at tips. If substances such as food scraps and other things like lawn clippings and hedge trimmings are buried in a tip, they can react over time to produce greenhouse gases.
- To conserve the resources from which things are made. For example, plastics are nearly all made from crude oil in one way or another. However, there are some important pharmaceuticals that also rely on crude oil.
- To save energy. For example, twenty aluminium cans can be recycled with the same amount of energy to produce just one new can.

FIGURE 5.35 Look closely at this photo. This is not garbage. All these things can be recycled, including cardboard, paper, egg cartons, steel cans, plastics and glass.

All methods of waste reduction rely on the physical and chemical properties of the materials involved. Three of the main ways that the amount of waste can be reduced are by:

- **Recycling**. This relies on the physical properties of the materials involved and physical changes that are then applied to them. Glass and some plastics are recyclable because they can be melted, reshaped and cooled.
- Using products that can be environmentally broken down into harmless substances. The processes involved here are chemical changes. For example, scientists have found a way to make a plastic derived from corn starch that is able to be broken down by sunlight.
- Making use of processes such as composting. This is especially useful for food scraps. In this process, the chemicals in the scraps undergo a chemical change, resulting in new products that can be used as fertiliser for growing plants.

5.8.2 Packaging

Just about everything you buy at the supermarket comes in a package. Even if it does not, you usually put it in a bag to take it home. The type of packaging needed depends on the properties of the product inside. For example, you cannot package tomato sauce in a paper bag. The most commonly used materials in packaging are paper (or cardboard), plastic, metal and glass. For a consumer, it is not just the properties of the packaging that are important. At least two questions should be asked when you make a choice about buying a product:

- Is the packaging recyclable?
- Is the packaging biodegradable?

If the packaging is glass, aluminium or steel, it is probably recyclable, which can save energy and water. If it is a plastic bottle, it is also likely to be recyclable. If the packaging is not recyclable, think about whether it is **biodegradable**; that is, can it be broken down by natural chemical reactions in the bodies of worms or other small **organisms** called **decomposers** that live in the soil? Plastics, metals and glass are non-biodegradable. If they are thrown out with other household rubbish such as food waste, they end up in rubbish tips and will not break down. This creates the need for more rubbish tips. Of course, there is a limit to how much land can be used for rubbish tips in or near major towns and cities.

Paper is mostly biodegradable. Paper packaging that has been contaminated by food or oils, however, cannot be recycled. But at least when it gets to the rubbish tip it can be broken down in the soil. If you have a choice, choose items with packaging that is either recyclable or biodegradable.

5.8.3 Recycling different materials

Plastics

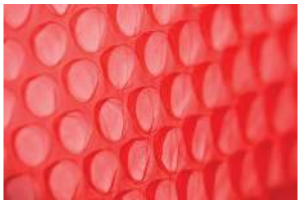
There are two very good reasons for recycling plastics:

- Plastics are non-biodegradable; that is, they are not broken down naturally by microorganisms. Plastics add thousands of tonnes of new rubbish to the environment every year.
- Plastics are made from oil — a resource that is expensive and dwindling. This is a chemical reaction. The continued production of new plastics is not **sustainable**. Recycling plastics is usually a physical change involving heat.

Household waste contains many different types of plastic, which need to be separated. The plastics industry has introduced a code system to help consumers identify recyclable plastics. The symbols shown in table 5.2 make the sorting of plastics before recycling easier and cheaper. Some plastics are more easily recycled than others because of differences in the structure of the chains of molecules of which they are made.

TABLE 5.2 Symbols for types of plastics and recycling

Symbol and name	Details	Examples of uses	Recycling information
 PET/PETE Polyethylene terephthalate	• Most used consumer plastic • Mainly for single-use products • Not heat resistant • Difficult to clean properly; should not be reused	Textiles such as fleece garments, carpets, stuffing for pillows and life jackets; soft drink and water bottles 	• Widely recycled • Empty PET bottles completely and remove the lids before placing them in a home recycling bin.

2 HDPE High-density polyethylene	• Hard wearing; does not break down • Stronger than PET • Reusable • Suitable for freezing	Compost bins; irrigation pipes and plumbing fittings; household bags; milk, juice, water and detergent bottles 	• Easily recycled • Empty HDPE bottles completely and remove the lids before placing them in a home recycling bin.
3 V PVC	• Can leach toxins • Not suitable for food and drinks • Useful for outdoor products because it doesn't break down • Produces toxic chemicals when heated and this limits the ability to be recycled	Juice and detergent bottles, PVC piping, credit cards 	• Not easily recycled but can be made into more PVC products such as flooring • PVC bottles can be placed in a home recycling bin as long as the lids are removed. They are separated from the more easily recyclable plastics and sent to a separate plant for processing.
4 LDPE Low-density polyethylene	• Thin and flexible • Easy and inexpensive to produce • Safe to use with food	Frozen food bags, bin liners, squeezable bottles, flexible container lids, cling film, carry bags and packaging film, bubble wrap 	• Bottles and other containers are recyclable and can be placed in a home recycling bin. • Soft, scrunchable plastics can often be returned to the supermarket for recycling (but it is best to avoid using them by using reusable bags for shopping).
5 PP Polypropylene	• Hard and lightweight • Withstands heat • Resistant to grease and chemicals • Safe to reuse	Reusable microwave containers, kitchenware, nappies, yoghurt containers, straws, disposable cups and plates, landscaping border stripping, battery cases, margarine tubs 	Can be recycled but depends on the product and local council

(continued)

TABLE 5.2 Symbols for types of plastics and recycling *(continued)*

Symbol and name	Details	Examples of uses	Recycling information
 PS Polystyrene	• Lightweight and soft • Flammable • Inexpensive to make • Easily moulded • Can release harmful chemicals, particularly if heated	Packing 'peanuts'; disposable cups, plates and trays; insulation, disposable takeaway containers 	Not easily recycled and must be disposed of in general waste; avoid use if possible
 OTHER Other	• Other plastics, including nylon, fibreglass and polycarbonate • Strong and tough • Possible release of hazardous BPA	Beverage bottles, baby milk bottles, electronic casing, lenses for sunglasses and safety goggles 	Generally not recyclable and should not be placed in your home recycling bin

Glass

About 45 per cent of the glass packaging used in Australia is recycled. Used glass bottles, known as **cullet**, are collected and melted down in a furnace to produce new products. This is a physical change. The overall energy saving is only eight per cent of that used in making new glass. This is because of the high cost of collecting and melting down the bottles. In some countries, milk is sold in bottles that can be sterilised and reused up to 50 times before they need melting down, which saves a large amount of energy.

Paper and cardboard

Over a million tonnes of paper — about a third of our annual consumption — is recycled in Australia. Paper is made out of fibres of the chemical cellulose and is relatively easy to recycle. Waste paper is first mixed with water to separate the fibres. Additives such as ink and adhesives are then removed, producing low-quality fibres that can be used to make cardboard and other products. Steam rollers are used to improve the quality of the finished paper. Recycling paper reduces the amount of new paper needed, saving millions of trees.

Metals

Metals such as steel and aluminium are easily recycled as long as they can be cheaply separated from other rubbish. Steel cans, aerosol containers, jar lids and bottletops can be recycled. The recycling of aluminium cans saves huge amounts of energy. Twenty aluminium cans can be recycled with the same amount of energy needed to produce just one new can.

ACTIVITY: Design your own waste disposal system

Your group is responsible for preparing a report on ways to improve the household waste management and disposal for the shire of Green Valley.

The shire currently collects rubbish from its 134 500 ratepayers using large green bins that are emptied by compactor trucks. The rubbish is taken to the local tip and used as landfill, at a cost to the council of $60 per tonne. The tip is nearing capacity and will be closed within 12 months. Waste paper is collected separately by a private recycling company.

Your report could be produced in written form or as audio or video. It should address the following issues:

1. How will the shire encourage each household to produce less waste?
2. Is recycling too costly?
3. If recycling occurs, will recyclable wastes such as plastics, glass and metals be separated at a disposal station after collection, or collected in separate containers from households?
4. What measures will be used to encourage households to use compost bins?
5. How will the shire dispose of rubbish when the landfill site closes?

5.8.4 Sorting out recyclables

The separation of the items in your recycling bin relies on differences in their physical properties, including size, weight, magnetic properties and even colour. For example, items of different weights can be separated using blasts of air or a centrifuge that works like the spin dryer of a washing machine. Steel can be separated from other metals by a large magnet. Organic waste, such as food scraps and garden waste, can be placed in compost bins instead of landfill, helping create nutrient-rich soil while reducing waste.

FIGURE 5.36 This compost bin is made from recycled polypropylene (PP). The compost decreases in volume as it breaks down. Almost 50 per cent of domestic waste in Australia is suitable for composting.

Special recycling programs

There are separate recycling programs for some products that cannot be placed in home recycling bins. These recycling programs are generally used to collect products containing substances that would endanger the environment or the community if they were dumped in landfill tips. For example, printer cartridges can be placed in recycling boxes at many Australia Post outlets and retail stores that sell computers and printers. Mobile phones can be left at most mobile phone outlets for recycling. Use the **Recycling weblink** in your Resources tab to find out where computers and other electronic equipment, white goods such as fridges and washing machines, corks, light globes and many other items are collected for recycling. This website also provides information about how to dispose of chemical wastes from home, school or industry. Oil, paints and unused medicines should not be placed in rubbish bins or flushed down the sink.

DISCUSSION

You may have noticed an increasing number of people collecting bottles and cans lately. The introduction of the Victorian Container Deposit Scheme has encouraged this by giving people 10 cents for every can or bottle they return.

In small groups, discuss the following.
1. Do you know where and how to return these articles in your area?
2. Why do you think the scheme only applies to bottles and cans at the moment?
3. This scheme has only been introduced in Victoria recently but has been operating for some time in other states. What do you think the reason for this is?
4. Where does the 10 cents that you get back come from?

5.8.5 You can make a difference

The three-bin collection system used by many city and shire councils throughout Australia makes it easy for you to make a difference to the environment by recycling.

For example, recycling paper:
- reduces the amount of energy needed to produce new paper
- prevents tonnes of greenhouse gases from entering the atmosphere from manufacturing new paper
- saves the many litres of water used in paper production; less water is used in recycling it.

5.8 Activities

learnon

5.8 Quick quiz on	5.8 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 5, 10	4, 6, 8, 9, 13	7, 11, 12

Remember and understand

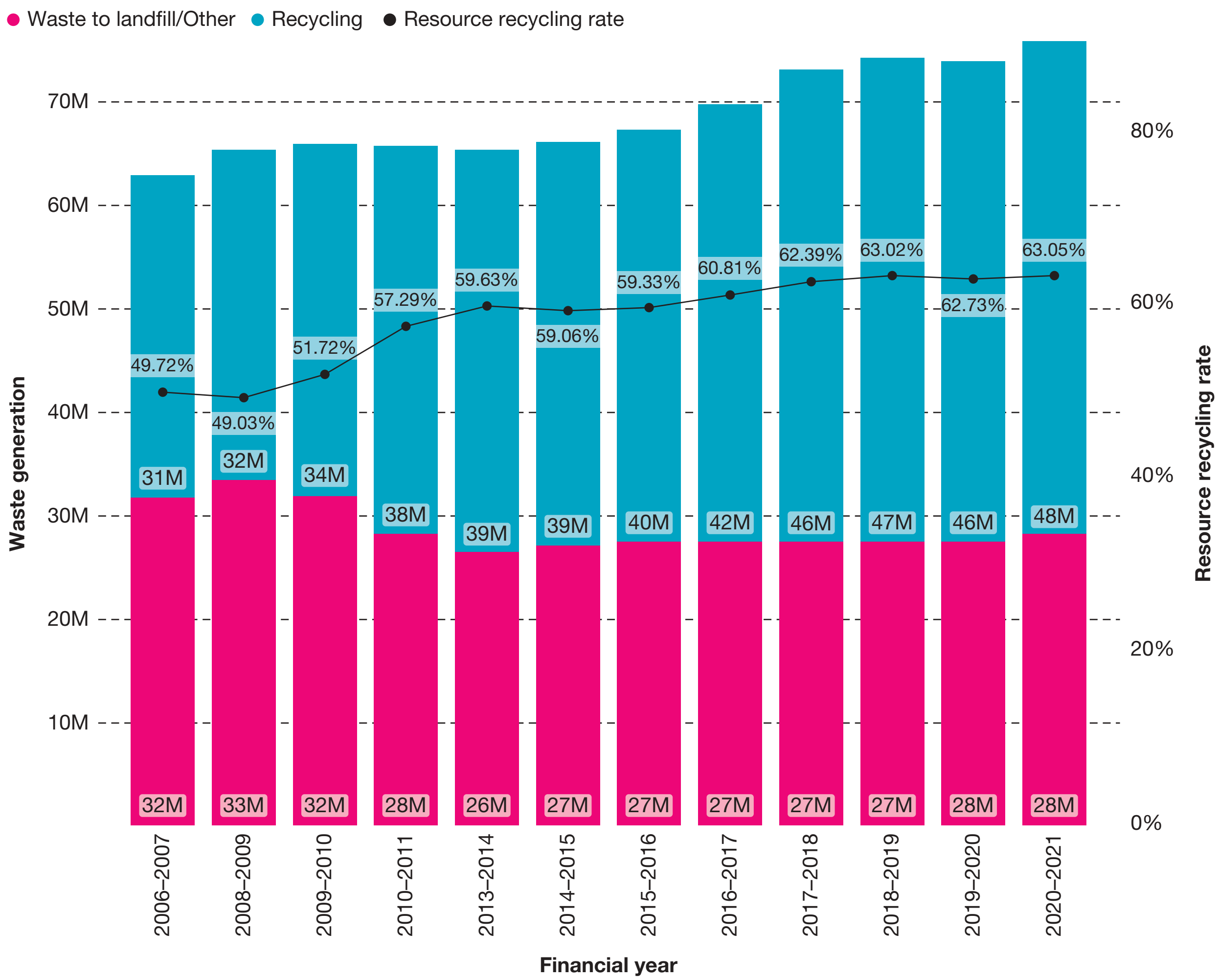
1. MC How are biodegradable substances different from those that are non-biodegradable?
   A. Non-biodegradable substances are referred to as such because they are not made from biological material.
   B. Biodegradable waste cannot be broken down by organisms in the soil.
   C. Biodegradable substances are referred to as such because they are made from biological material.
   D. Biodegradable waste can be broken down by organisms in the soil.
2. **Recall** and **state** where the chemical changes that break down biodegradable waste take place.
3. **Identify** two of the main benefits of recycling plastics.
4. MC Why are plastics such as PET now identified by a code?
   A. To identify how long plastics can be used for
   B. To identify which plastics can be heated
   C. To identify which plastics can be recycled
   D. To identify which plastics are safe for food items
5. MC The first part of the process of recycling paper involves mixing it with water. What is the major purpose of mixing the paper with water?
   A. To begin the chemical reaction that breaks down paper
   B. To cause a change of state from solid to liquid
   C. To increase the effect of temperature
   D. To weaken the forces between the fibres

6. **List** three problems associated with the disposal of waste in landfill sites.
7. a. True or false? Only a small amount of energy is saved when glass is recycled.
   b. **Explain** your response to part a.
8. **List** two benefits of recycling aluminium.
9. Ink is removed from paper when it is recycled. Is the combination of ink and paper a compound or a mixture? **Explain** your answer.

Apply and analyse

10. Most plastics are non-biodegradable. Metals and glass are also non-biodegradable.
    a. What does biodegradable mean?
    b. If non-biodegradable rubbish cannot be recycled, what happens to it?
11. SI The following graph shows the amount of waste that went to landfill compared to the amount of waste that was recycled between 2006 and 2021.

Waste generation (tonnes) and recycling rate



Source: Based on data from Department of Climate Change, Energy, the Environment and Water. 2022. Waste and Resource Recovery Data Hub — National waste data viewer.

From this graph:
a. **identify** which method of dealing with waste was the least used in the years from 2006 until 2021
b. **describe** the general trend in waste going to landfill.

Evaluate and create

12. a. **List** the factors that determine whether it is worth the trouble of recycling a resource.
    b. SI Which of these factors can be investigated scientifically?
13. SI Consider different alternatives to plastics that have recently been developed or are currently being developed. **Discuss** one alternative and **explain** how it compares to recyclable materials such as glass, metal and paper in terms of environmental impact and how it is processed after use.

Answers and sample responses are available in your digital formats.

LESSON 5.9 Making use of properties — identifying some mystery powders

LEARNING INTENTION

In this lesson you will describe how physical and chemical properties can be used to identify some unknown substances.

5.9.1 What is analysis?

In science, **analysis** is identifying the substances that are present. It can be done on a number of different levels. For example, it can be used to identify:

- an unknown substance
- the components of a mixture
- the elements present in a compound.

Analysis is a very common procedure. One example that you have already met in this topic is the testing of urine samples for prohibited substances in sport. Some other situations occur in pharmaceutical manufacturing to ensure drug purity, in forensic science and in environmental science to monitor air, water and soil. There are many more examples!

5.9.2 How is scientific analysis performed?

Scientific analysis can be performed in a number of ways. These include:

- using simple laboratory tests and carefully noting observations
- other laboratory tests and procedures that involve careful measurements
- using sophisticated analytical equipment. These instruments can be sensitive and are often very expensive.

FIGURE 5.37 A team of medical research scientists conducting analysis in a laboratory.

KEY IDEA

In science, analysis is the process of identifying substances or elements that are present in a sample.

ACTIVITY: A scenario — which powder is that?

Imagine that the teachers of the Food Technology department at your school have come to you for help. They have been cleaning out an old pantry and have come across some jars containing white powders. These jars have been there for so long that their labels have fallen off. The teachers think they know what each one might be, but they need to be sure.

Your job is to identify each one for them.

The powders are known to be:

- salt
- baking soda (also known as bicarb of soda)
- sugar
- starch
- cream of tartar
- baking powder
- plaster (they're not sure how this one got into the pantry!).

To identify these, you will make careful observations of both their **physical** and **chemical** properties.

You will do this in two stages. First, you will make your observations on known samples of these substances. You will then apply the same tests to the unknown samples and compare your results to the first stage. Ideally, you should be able to identify each of the powders this way. If not, you will no doubt be able to narrow down the possibilities and suggest further tests that might help.

Some good tests to utilise would be:

- colour
- appearance
- reaction to vinegar (vinegar contains acetic acid)
- reaction to water
- pH of any resulting solution
- reaction to iodine solution.

INVESTIGATION 5.15

Identifying some mystery powders

Aim

To identify a number of mystery powders

Materials

- spotting plate
- test tubes and test tube rack
- spatulas
- hand lens
- iodine solution
- vinegar
- universal indicator solution
- microscope (optional)
- samples of salt, baking soda, sugar, starch, cream of tartar, baking powder and plaster
- samples of the unknown powders, labelled A to G

Method

Part A

1. Create a table with the tests (colour, appearance, reaction to vinegar, reaction to water, pH, reaction to iodine solution) listed across the top and the known substances down the side.
2. Use a spatula to place a small amount of each powder into separate wells on the spotting plate.
3. Examine each sample using a hand lens and note its colour and anything distinctive. Record your observations in your table from step 1.
4. Use a spatula to place a small amount of each known substance into separate test tubes. Add about 1–2 cm depth of vinegar and gently shake. Record your observations.
5. Clean your test tubes from step 4. Use a spatula to place a small amount of each known substance into separate test tubes. This time, add about 1–2 cm depth of water and shake. Record your observations.
6. Now, add a few drops of universal indicator to each test tube from step 5. Use a pH chart to estimate the pH in each test tube.
7. Clean your test tubes from step 6. Use a spatula to place a small amount of each known substance into separate test tubes. Now, add a few drops of iodine solution to each test tube and note any colour change. You might also like to add a little water if you think it necessary.

Part B

8. Create another table similar to that in step 1, but with the letters A to G (the unknown powders) down the side.
9. Repeat steps 2 to 7 with each of the unknown samples. Make sure you record your results in your new table.

Results

Your two tables will form your results.

Discussion

1. Name the powders that were the easiest to identify. Explain why.
2. Name the powders that were more difficult to identify. Explain why.

Conclusion

Identify the names of the samples listed A to G.

Extension

A microscope might be available for you to use instead of a hand lens.

Heating a sample and observing what happens is another test you might perform.

5.9 Activities

learnon

5.9 Quick quiz on	5.9 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 3, 7	2, 6, 8	4, 5, 9

Remember and understand

1. **Name** a substance that iodine can be used to test for. What would you observe when such a test is performed?
2. The table below shows three substances that are being tested in two ways.
   Place a tick or a cross in each part of the table to show whether or not a reaction occurs.

	Reacts with acid	Reacts with iodine
Starch		
Sugar		
Cream of tartar		

3. MC What would you expect to observe when water is mixed with baking powder?
   A. The powder will dissolve without anything else happening.
   B. The solution will turn a dark blue.
   C. The powder will not dissolve and the water will look milky.
   D. The powder will dissolve and bubbles of gas will appear.
4. Match each substance from the left-hand list with a correct statement from the right-hand list.

Cream of tartar	Produces bubbles when water added
Starch	Produces a pH of less than 7 when water added
Baking powder	Dissolves in water
Sugar	Turns iodine solution blue

Apply and analyse

5. When baking soda is mixed with vinegar, a gas is produced. **Outline** how you could prove the gas is carbon dioxide.
6. Refer back to investigation 5.15. With reference to the method and the results you obtained, which two substances are the most difficult to uniquely identify? **Explain**.

Evaluate and create

7. Refer back to investigation 5.15. Do you think part A needs to be done before part B, or can these parts be done the other way round? **Discuss**.
8. **Construct** a scientific poster to display your method and results from investigation 5.15.
9. Refer back to Investigation 5.15. **Outline** an improved method.

Answers and sample responses are available in your digital formats.

LESSON 5.10 Review

5.10 Success criteria

Tick the column to indicate that you have completed the lesson and how well you think you have understood it using the traffic light system.

(**Green:** I understand; **Yellow:** I can do it with help; **Red:** I do not understand)

Lesson	Success criteria	Green	Yellow	Red
5.2	I can identify the difference between chemical and physical changes, and how these can be described using word equations.			
5.3	I can recognise that chemical reactions begin with reactants, which are changed into products.			
	I can write word equations for chemical reactions.			
5.4	I can recognise that corrosion is a reaction in which the chemical and physical properties of metals are changed as they break down, which affects their use.			
	I can describe the processes of surface protection and galvanising to prevent corrosion.			
5.5	I can identify that one familiar reaction that causes a temperature change is combustion, which is the reaction of fuels with oxygen to produce heat and products that often contain carbon dioxide and water.			
5.6	I can discuss where indicators of chemical change are used in order to identify the presence of particular substances, such as in soil, water and medical testing kits.			
5.7	I can describe examples of how plastics and fibres or their blends can be developed for a particular purpose.			
5.8	I can identify the types of plastics that are easily recyclable and those that are more difficult.			
	I can understand how glass, metal and paper products can be sorted and recycled in a recycling facility.			
5.9	I can describe how physical and chemical properties can be used to identify some unknown substances.			

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Post-test	Topic 5 Post-test
eWorkbook	Topic 5 eWorkbook
Digital document	Key terms glossary

5.10 Activities

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5.10 Review questions

LEVEL 1	LEVEL 2	LEVEL 3
1, 5, 7, 13, 15, 17	2, 6, 10, 11, 12, 14, 19	3, 4, 8, 9, 16, 18, 20

Remember and understand

1. Match the substances on the left to the list of properties on the right.

Substance	Properties
a. Glass	A. Flexible, biodegradable
b. Metal	B. Transparent, unreactive, strong
c. Plastics	C. Malleable, ductile, good electrical conductor
d. Paper	D. Mouldable, light, strong

2. a. True or false? Physical properties are those that you can observe or measure using your senses or measuring instruments. Chemical properties are those that describe how a substance combines with other substances.
   b. **Explain** your response to part a.
3. Match the property on the left to its meaning on the right.

Property	Meaning
a. Ductile	A. Able to be rolled or beaten into sheets
b. Reactive	B. Substances that can damage living things when taken into the body
c. Malleable	C. Readily combines chemically with other substances
d. Lustrous	D. Lets light through without scattering
e. Toxic	E. Temperature at which a solid changes into its liquid form
f. Transparent	F. Able to be drawn into wires
g. Melting point	G. Shiny

4. **Identify** which of the following scenarios is a chemical change or physical change. Then write a word equation describing the change.
   a. The wax on a burning candle melts.
   This is a _____________ change.
   _____________ ⟶ _____________
   b. The wax vapour at the top of a candle wick burns with oxygen to produce carbon dioxide, water vapour and heat.
   This is a _____________ change.
   wax vapour + _____________ ⟶ _____________ + water
   c. Calcium carbonate is dissolved by hydrochloric acid to form calcium chloride, water and carbon dioxide gas.
   This is a _____________ change.
   solid calcium carbonate + ___________ ⟶ ___________+ carbon dioxide gas + water
   d. Hydrogen gas explodes with oxygen gas to form water.
   This is a _____________ change.
   _________________ ⟶ _________________

5. MC How do you know that toasting bread and the rusting of a nail are not physical changes?
   A. A new colour is produced.
   B. A new chemical has been formed.
   C. A gas is produced.
   D. Heat is produced.
6. When a lead nitrate solution is added to a potassium iodide solution, a chemical reaction takes place. A bright yellow solid appears. It is the compound lead iodide. Another compound, potassium nitrate, remains in the solution and is not visible.

   a. MC Which of the following are the reactants in the reaction? Select all possible answers from the options given.
      A. Lead nitrate
      B. Lead iodide
      C. Potassium iodide
      D. Potassium nitrate
      E. Water
   b. MC Which of the following are the products in the reaction? Select all possible answers from the options given.
      A. Lead nitrate
      B. Lead iodide
      C. Potassium iodide
      D. Potassium nitrate
      E. Water
   c. The yellow lead iodide will eventually settle to the bottom of the flask. **Name** the 11-letter word beginning with 'p' that is given to a substance that behaves like the lead iodide.
   d. MC Which of the following is the chemical word equation for the reaction?
      A. Lead iodide + potassium iodide ⟶ lead nitrate + potassium nitrate
      B. Lead nitrate + lead iodide ⟶ potassium iodide + potassium nitrate
      C. Lead iodide + potassium nitrate ⟶ lead nitrate + potassium iodide
      D. Lead nitrate + potassium iodide ⟶ lead iodide + potassium nitrate
7. a. True or false? The chemical word equation for rusting is:

$$\text{iron + water + carbon dioxide} \longrightarrow \text{rust (iron oxide)}$$

   b. **Explain** your response to part a.
8. SI Three substances — flour, sugar and bicarbonate of soda — were tested separately with acid and iodine. Complete the table by placing either a tick or a cross in each cell to indicate the expected reaction(s) for each substance.

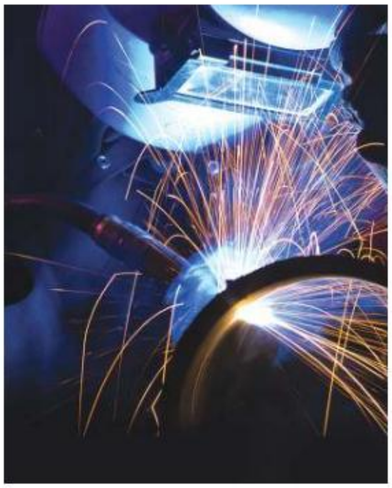
Substance	Reacts with acid	Reacts with iodine
Flour		
Sugar		
Bicarbonate of soda		

9. Some chemical reactions can be destructive. **List** three examples of harmful chemical reactions.

Apply and analyse

10. Children's steel swing sets in beachside towns and suburbs rust much faster than those further from the coast.
   a. **Explain** why this happens.
   b. **Suggest** two methods of slowing down or preventing the rusting of steel swing sets.

11. The oxyacetylene torch shown is used to melt metals to allow them to be joined together.



a. MC What type of chemical reaction takes place in the oxyacetylene torch?
A. Corrosion reaction
B. Combustion reaction
C. Addition reaction
D. Rusting reaction

b. MC What is the evidence in the photo that suggests a chemical reaction has taken place?
A. A bright light and small sparks are being produced.
B. The photo is mostly dark.
C. The welder is wearing gloves.
D. The welder is wearing a face shield.

12. Just as chemicals can be grouped or classified, so can chemical reactions. Match the chemical reactions on the left to the type of reaction on the right.

Chemical reaction	Type of reaction
a. The corrosion of iron	A. Combustion
b. The reaction of substances with oxygen	B. Rusting
c. Burning	C. Oxidation

13. This illustration shows a camper boiling water in a billy over a camp fire.

a. **State** the three physical changes that are shown in the image.
b. **Identify** which chemical change is shown taking place.

14. **List** two properties of the plastic used to make light switches and power points that make it right for the job.

15. MC What is the difference (other than their properties) between natural and synthetic fibres?
A. Natural fibres are made from plants, whereas synthetic fibres are made from animals.
B. Natural fibres are made from plants or animals, whereas synthetic fibres are made from crude oil.
C. Natural fibres are made from animals, whereas synthetic fibres are made from plants.
D. Natural fibres are made from crude oil, whereas synthetic fibres are made from plants or animals.

16. Classify whether each of the fibres listed are natural, synthetic or a combination of both.

Fibre	Synthetic	Natural	Combination
a. Nylon			
b. Cotton			
c. Rayon			
d. Lycra			
e. Wool			
f. Polyester			

17. **Explain** how synthetic fibres, such as nylon, are made.
18. Match the substances on the left to the properties that would be essential for their packaging on the right.

Substances	Properties of packaging
a. Pool chemicals	A. Gas-tight, strong, chemically resistant to the drink
b. Eggs	B. Airtight, opaque to light
c. Soft drink	C. Resistant to the chemicals inside, opaque to light
d. Peanuts	D. Lightweight, strong, rigid

Evaluate and create

19. SI Some plastic containers are marked with the symbol shown.

a. MC Which two of the following substances would you expect to find in bottles made from this type of plastic?
   A. Wine
   B. Soft drink
   C. Eggs
   D. Milk

b. MC What two things should you do before placing bottles made from this type of plastic in a recycling bin?
   A. Fill them up with water.
   B. Empty the contents.
   C. Remove the lids.
   D. Screw on the lids.

c. MC Which two of the following are uses for this type of plastic after it has been recycled?
   A. Carpet fibres
   B. This plastic cannot be recycled
   C. Paper
   D. Glass bottles
   E. Flower tubes

20. SI **Describe** the 'three-bin system' used by many cities and shires in Australia, and **explain** how it helps the environment.

Answers and sample responses are available in your digital formats.

on To test your understanding and knowledge of this topic, go to your learnON title at www.jacplus.com.au and complete the **post-test**.

6 Dynamic Earth

CONTENT DESCRIPTION

Earth is a dynamic planet as demonstrated by tectonic activity, including the formation of geological features at divergent, convergent and transform plate boundaries; the theory of plate tectonics is supported by scientific evidence (VC2S8U10)

Source: Victorian Curriculum F–10 Version 2.0

LESSON SEQUENCE

LESSON 6.1 Overview

6.1.1 Introduction

The ground you stand on might seem still and boring. But do not be fooled! Earth's outer rocky layer, called the **crust**, is made up of giant pieces called **tectonic plates**. These plates are always moving, even if you do not notice it. Their movement can cause **earthquakes** or create amazing **volcanoes**.

Take the Icelandic volcano Mount Fagradalsfjall, Iceland (figure 6.1). It is a perfect example of how Earth is alive and constantly changing. Watching these eruptions can be amazing — and a little scary too!

Over 80 per cent of Earth's volcanoes and earthquakes happen where tectonic plates meet. In Iceland, two plates are pulling apart, creating cracks in the crust. Hot rock rises through these cracks, melts and erupts as incredible volcanoes.

FIGURE 6.1 Lava flow on Mount Fagradalsfjall, Iceland

DISCUSSION

1. How can something as large as a continent move?
2. What did the world map look like 250 million years ago?
3. Why do the Himalayas have many of the highest mountains on Earth?
4. What is the 'ring of fire' around the Pacific Ocean?
5. What causes tsunamis?
6. Where has there been a significant earthquake and/or volcanic eruption in the last year?
7. Can natural events such as earthquakes and volcanic eruptions be predicted?
8. What other planets in our solar system have volcanoes? Where is the largest?

SCIENCE INQUIRY: Journey to the centre of the Earth

'Descend into the crater of Yokul of Sneffels, which the shade of Scataris caresses before the Kalends of July, audacious traveller, and you will reach the centre of the Earth.'

These words come from Jules Verne's 1864 science fiction novel *Journey to the Centre of the Earth*. The story follows Professor Lidenbrock, his nephew Axel and their guide Hans as they embark on an exciting adventure to explore Earth's hidden depths. Their journey starts in Iceland, where they descend into the crater of an extinct volcano called Snæfellsjökull.

While no one has actually been to the centre of the Earth, scientists have made amazing discoveries about what lies beneath our feet. The Earth's interior, also known as the **geosphere**, is layered with the crust on the surface, the **mantle** beneath it and a core at the very centre.

FIGURE 6.2 The layers of Earth

Think about the geosphere

Each layer of the geosphere becomes denser towards the centre. Scientists suggest that when Earth was forming, heavier materials sank to the bottom while lighter ones stayed on top.

1. Scientists have estimated Earth to be approximately a sphere with an average radius of 6370 km. Construct a scaled-down model for the interior of Earth. This model will help you visualise the three basic compositional layers.

TABLE 6.1 Depth to each layer of Earth

Earth layer	Average depth to top of layer	Average depth to bottom of layer
Crust	0 km	5–70 km
Mantle	5–70 km	2900 km
Core	2900 km	6370 km

Think about the crust

When you look at a map of the Earth, you will notice two major features: vast oceans and large land areas called continents. These features highlight the two basic types of crust: continental crust (found under land) and oceanic crust (found under oceans).

2. The continental crust and oceanic crust have different densities because they are made of varying amounts of different rock types. Continental crust has the bulk density of a rock type called 'granite', while oceanic crust is closer to the density of a rock type called 'basalt'.
   a. What are the densities of these rock types?
   b. Which type of crust is heavier — continental or oceanic?
3. There is a wide range of thickness in the crust (5–70 km) due to the varying densities. Which do you think is thinner — continental or oceanic?
4. Construct a hypothesis that relates the type of crust to its density and thickness.

Think about the mantle and core

Earth's crust is shaped by the dynamics of the layers beneath it. As you go deeper, pressure increases from the weight of rocks above, and temperature rises due to friction and heat from radioactive materials.

5. How do you predict rocks would behave when under increased confining pressure — stronger or weaker?
6. How do you predict rocks would behave when temperature increases — stronger or weaker?
7. With this battle between increasing pressure and temperature, what do you imagine the state of the mantle to be like?
8. Jules Verne described Earth's interior to be full of interconnected caverns. How valid is his description?
9. Earth's surface is constantly experiencing change. List five natural events that cause change to the surface and evaluate which ones may be the result of a dynamic interior.

Investigable questions, reasoned predictions and hypotheses can be developed in guiding investigations to identify patterns, test relationships and analyse and evaluate scientific models (VC2S8I01)

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Pre-test	Topic 6 Pre-test
eWorkbooks	Topic 6 eWorkbook Student learning matrix
Practical investigation eLogbook	Topic 6 Practical investigation eLogbook
Digital document	Key terms glossary

LESSON 6.2 Earth's dynamic layers

LEARNING INTENTION

In this lesson you will:

- describe Earth's internal layers
- discuss the theory of continental drift and the formation of the supercontinent Pangaea.

6.2.1 Structure of Earth

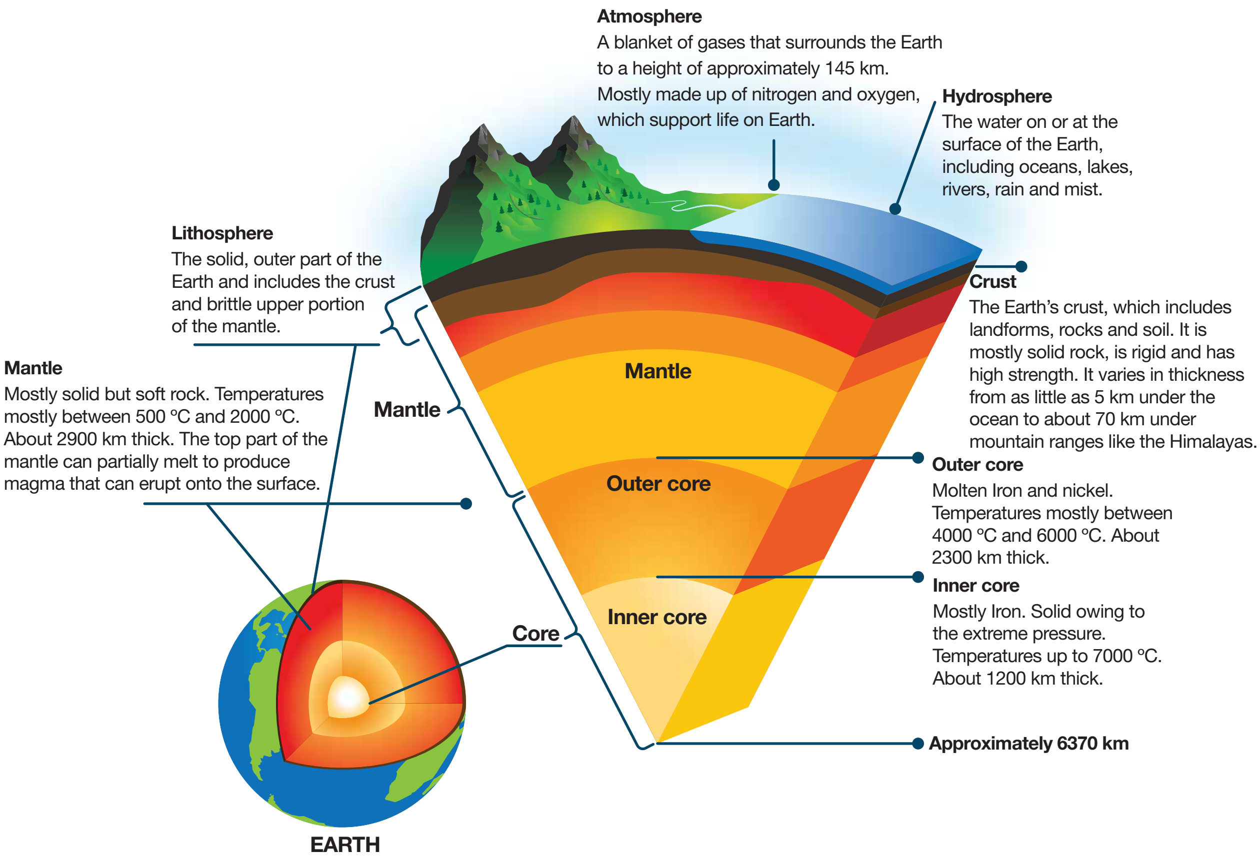
The Earth is made up of layers, and scientists describe them in two ways.

- *What they are made of:* The crust, mantle and **core** are layers divided by density. Material made of heavy elements such as iron sank to the core, and lighter ones such as those made of oxygen and silicon stayed closer to the surface.
- *How they behave:* As you go deeper into the Earth, pressure and temperature battle it out. This can make some parts stronger and others weaker. The core has a solid inner part and a molten (melted rock) outer part. The **lithosphere**, which includes the crust and part of the mantle, is solid and can break. Below the lithosphere, the rest of the mantle is mostly solid but softer, with some parts experiencing partial melting.

KEY IDEA

The **inner core** is solid, even though it is incredibly hot, because the extreme pressure from all the layers above keeps it tightly packed and raises the melting point. In contrast, the **outer core** is molten because it has less pressure above it, dropping the melting point, which allows the intense heat to melt the iron mixture.

FIGURE 6.3 Layers of Earth



We cannot dig deep enough to see these layers. In fact, the deepest hole ever drilled, the Kola Superdeep Borehole in Russia, went down only 12 km — tiny compared to the 6370 km to Earth's centre!

So how do scientists know what's inside? They use methods such as:

- studying meteorites from space
- testing rocks under high heat and pressure in labs
- analysing **seismic waves** from earthquakes, which have travelled through the Earth
- learning from earthquakes and volcanoes
- examining Earth's gravitational field anomalies.

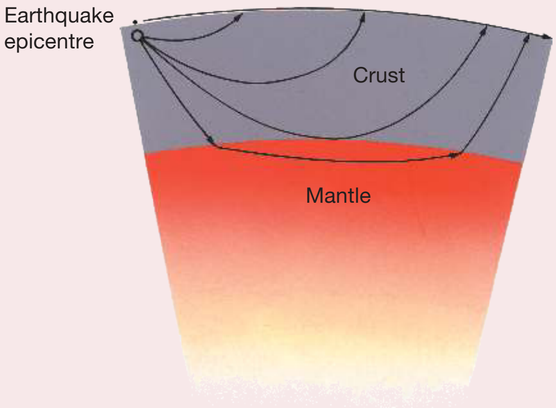
These methods help us discover what is deep under our feet.

SCIENCE AS A HUMAN ENDEAVOUR: Imaging the interior of Earth

Geophysicists use data from earthquakes to find out what lies inside Earth. Earthquakes produce seismic waves that transfer energy from the site of the earthquake (the **focus**) through the crust. It is the energy of these waves that causes destruction at the surface.

Seismic waves travel differently (speed and behaviour) as they pass through different substances below the crust. By analysing seismic waves, scientists have been able to identify the state and chemical composition of the substances inside Earth. For example, Earth's core is likely made of iron and nickel, but is divided into two layers: a liquid outer core and a solid inner core. Flow of the liquid outer core plays an important role for life on Earth, as it generates Earth's magnetic field, which protects the surface from some of the most harmful solar radiation.

FIGURE 6.4 Seismic waves travel through Earth and return to the surface. When they interact with a new medium, like at the base of the crust (grey), the speed and travel path of the waves is altered. The epicentre is the point on Earth's surface vertically above the focus.



1. How do seismic waves behave differently when passing through solids and liquids, and what does this reveal about Earth's interior?
2. Why are earthquakes important for understanding the composition and state of Earth's layers?
3. What role does Earth's magnetic field play in protecting life on the surface?
4. Besides protecting against harmful solar radiation, what other uses does the magnetic field have?
5. The outer core generates the magnetic field, but are there other layers of Earth that also experience movement? If so, how does this movement impact the surface?
6. How might new discoveries about Earth's interior refine our current models and understanding of its structure?

Scientific knowledge, including models and theories, can change because of new evidence (VC2S8H01)

6.2.2 The crust

The shapes and features of Earth's crust give clues to geologists about things that are happening deep beneath the surface. Geologists discovered that there are two types of crust: continental crust, which makes up the land, and oceanic crust, which forms the ocean floors.

In some rare places, pieces of oceanic crust have been found on land. These rocks, called **ophiolites**, have helped scientists learn more about the differences between the two types of crust (table 6.2). One example is Macquarie Island, an ophiolite in the Pacific Ocean, halfway between New Zealand and Antarctica. It is part of Tasmania and is even a UNESCO World Heritage Site.

TABLE 6.2 Thickness and density of continental crust and oceanic crust

Continental crust	Oceanic crust
Ranges from 25 to 70 km thick	Ranges from 4 to 10 km thick
Average density is 2.7 g/cm^3, similar to the rock granite	Average density is 3.0 g/cm^3, similar to the rock basalt

DISCUSSION

Where do you think the thickest continental crust would be? How could a geologist test your hypothesis?

6.2.3 Moving continents

In the 1800s, most geologists thought Earth started as a hot, molten ball of rock. As it cooled, a solid crust formed, and Earth began to shrink. They believed this shrinking caused the crust to wrinkle, like the skin of a rotting apple. The high parts of these 'wrinkles' were thought to form continents and mountains, while the low parts became oceans. According to this idea, mountains, volcanoes and earthquakes would happen randomly across Earth.

All scientific theories can change as new evidence is discovered. In the late 1800s and early 1900s, scientists were beginning to collect observations that suggested the continents were actually moving.

The continental drift theory

In 1912, a German meteorologist and polar explorer named Alfred Wegener introduced a bold new idea. He suggested that, instead of the Earth shrinking, the continents were slowly drifting across a softer layer of the mantle beneath them. He proposed that continents push through oceanic crust and sometimes collided with one another. This theory became known as **continental drift**.

Wegener also believed that, millions of years ago, all the continents were joined together like pieces of a giant jigsaw puzzle. He called this supercontinent **Pangaea**, which was surrounded by a vast ocean called **Panthalassa** and a smaller sea named Tethys.

About 200 million years ago, Pangaea began to break apart and the continents then eventually drifted to their current positions.

Wegener's theory was based on several lines of evidence:
- The continents appeared like they could fit together, like puzzle pieces.
- **Fossils** of the same land plants and animals were found on continents separated by oceans.
- Unique rocks and land features of the same age were found on different continents.
- Plant fossils were discovered in places where the climates were very different to where the plants would have grown.

FIGURE 6.5 The supercontinent of Pangaea as it would have appeared 200 million years ago, surrounded by the Panthalassa Ocean

DISCUSSION

In what ways did continental drift affect the evolution of animals and plants living on Earth at the time?

INVESTIGATION 6.1

Continental drift

Aim

To create a simple model to demonstrate continental drift

Materials

- enlarged copy of the map
- scissors

Method

1. Cut out the continents from the enlarged copy of the map provided.
2. Examine the distribution of fossils on each continent.
3. Rearrange the continents into one supercontinent by matching the distribution of fossils. For example, you want the pink trend of the *Glossopteris* (fern) fossil on one continent to align with another trend on a different continent.

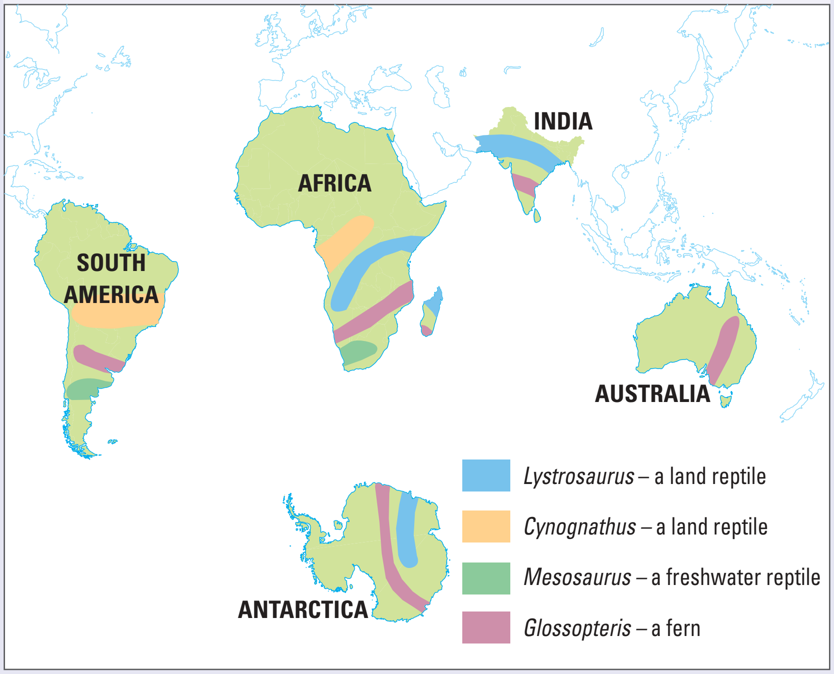
Results

1. Once you have rearranged the continents for your model, glue them into your logbook.
   a. What continent aligns with the east side (right side) of South America?
   b. Is there a continent along the southern margin of Australia?
2. Note which continents must be rotated from their modern-day positions.

Discussion

1. Why is the distribution of land-based fossils used as evidence of continental drift?
2. What part of Pangaea does your landmass represent?
3. What latitude and climate conditions during the time of Pangaea would you predict for Australia? How could you investigate your hypothesis?
4. How valid do you think your results are? (*Hint:* Compare your result with others around you; did everyone come up with the same configuration? Is there more than one possible configuration?)
5. Suggest at least one other line of evidence that you could look for that would strengthen your results.

Distribution of a selection of fossils of ancient organisms



Conclusion

Summarise the findings from this investigation about continental drift.

6.2 Activities

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6.2 Quick quiz	6.2 Exercise

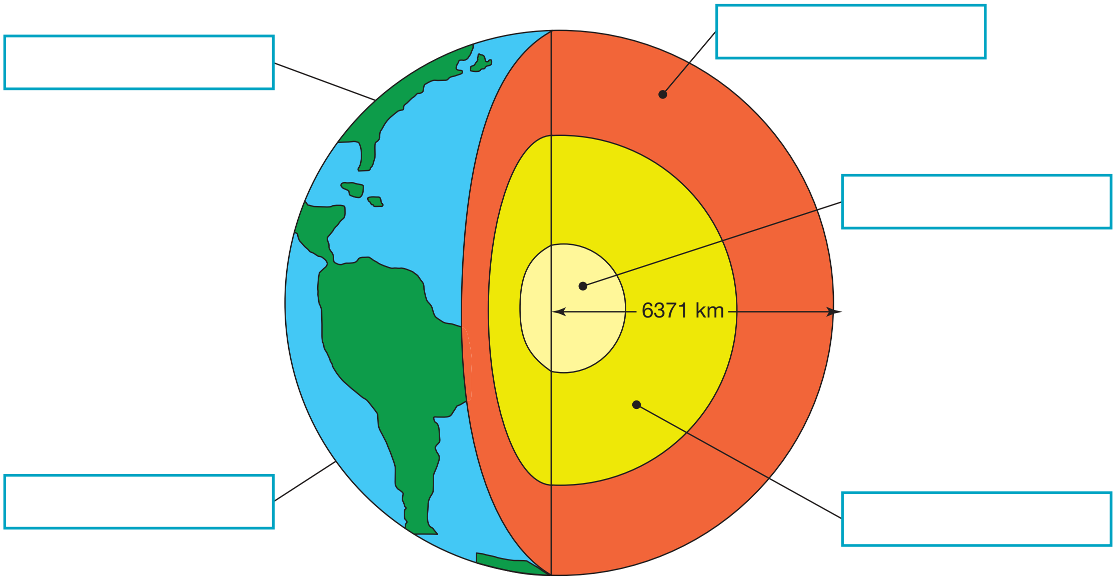
LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 7	3, 4, 6, 10, 11	5, 8, 9, 12

Remember and understand

1. Complete the table by adding descriptions for each of Earth's layers.

Layer	Description
Atmosphere	
Hydrosphere	
Crust	
Mantle	
Outer core	
Inner core	

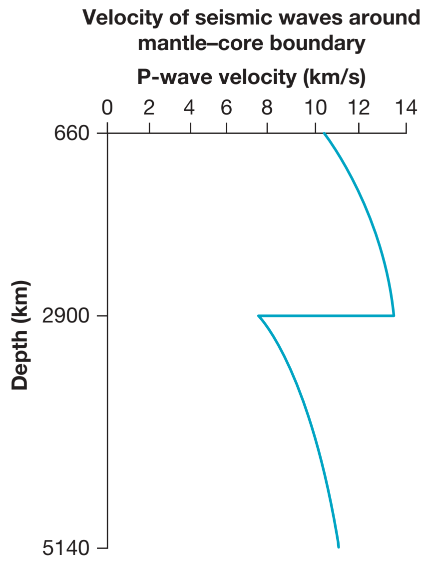
2. Provide the appropriate labels for the model of Earth shown (*remember the two different types of crust*).



3. Even though the inner core is hotter than the molten outer core, it is solid. **Explain** why this is the case.
4. **Explain** how oceanic crust is different from continental crust.
5. **Describe** two observations that provided evidence for Wegener's theory of continental drift.
6. According to Wegener's theory of continental drift, **name** the layer of Earth upon which the continents are floating.
7. **State** what Pangaea and Panthalassa were.

Apply and analyse

8. **Explain** how the study of meteorites might improve our understanding of Earth's interior.
9. SI Seismic waves travel fast, measured in kilometres per second (km/s). The velocity changes of a seismic wave for the depths around the mantle–core boundary within Earth are shown in the graph.
   a. **Identify** and mark the boundary between mantle and core.
   b. What variables can influence the speed of the seismic wave? **Explain** your answer.



10. **Explain** why geologists have not been able to drill a hole deeper than 12 km, considering the distance to the centre of the Earth is over 6000 km deep.

Evaluate and create

11. SI The Shrinking Earth theory was popular during the 1800s to explain the existence of continents and mountain ranges.
    a. **Outline** how it explained the existence of continents, particularly mountain ranges.
    b. **Suggest** an investigation that could help test the theory.
12. SI Alfred Wegener's theory of continental drift was not widely accepted, despite all the evidence put forward. **Suggest** why the scientific world may have had a hard time accepting continental drift, as he proposed it.

Answers and sample responses are available in your digital formats.

LESSON 6.3 The theory of plate tectonics

LEARNING INTENTION

In this lesson you will discuss Marie Tharp's contribution to the theory of plate tectonics and the different forces involved in plate movement.

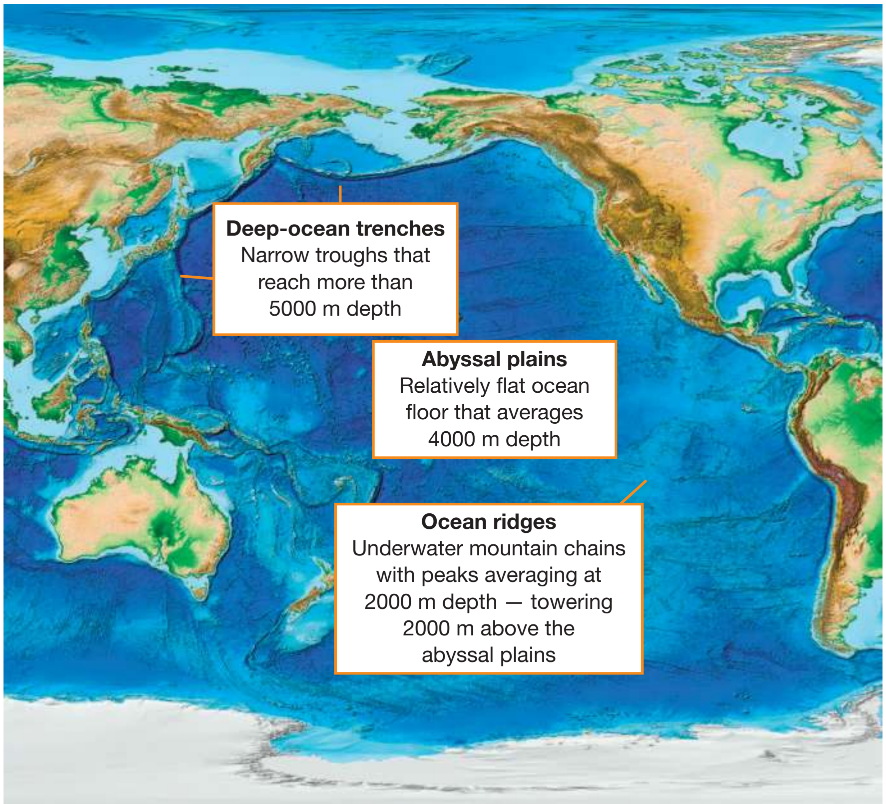
6.3.1 Mapping the sea floor

At first, Alfred Wegener's idea of continental drift was not widely accepted because he was not able to explain how the continents moved. It was not until the 1940s, when scientists began studying the sea floor, that the pieces of the puzzle started to come together.

During World War II, submarines used sound waves (called echosounding) to avoid obstacles and locate other submarines. A naval officer and geologist named Harry Hess used this technology to start mapping the ocean floor. Soon after, others, including Marie Tharp, joined in. They discovered that the ocean floor is not flat (like the **abyssal plains**) but has surprising features like underwater mountain chains called **ocean ridges** as well as **deep-ocean trenches**.

By the 1960s, much of the ocean floor had been mapped, and geologists noticed something interesting: rocks farther from ocean ridges were older and colder, while rocks closer to the ridges were younger and hotter. This led to the idea of **sea-floor spreading**.

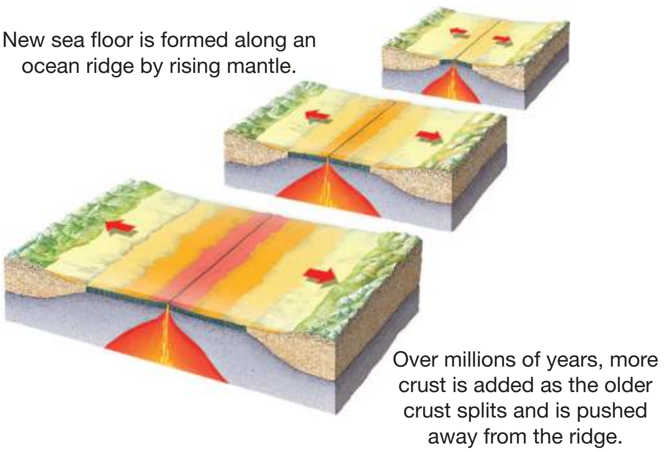
FIGURE 6.6 This topographic model of the Pacific Ocean highlights sea-floor features such as abyssal plains, ocean ridges and deep-ocean trenches. The Mariana Trench of the western Pacific is the deepest place on Earth, with a depth of 10.9 km — deep enough to swallow Mount Everest without a trace.



KEY IDEA

Sea-floor spreading happens when new oceanic crust forms at the centre of ocean ridges. Hot mantle material rises, melts and erupts through underwater volcanoes, creating new crust as it cools. This new crust pushes the older crust away from the ridges, causing the ocean basin to grow wider over time.

FIGURE 6.7 The process of sea-floor spreading can move continents apart.



SCIENCE AS A HUMAN ENDEAVOUR: Marie Tharp - pioneering ocean explorer

Marie Tharp was a geologist and cartographer who transformed our understanding of Earth, despite facing challenges as a woman in a male-dominated field. In the 1940s and 1950s, Tharp worked with Bruce Heezen to map the ocean floor in the North Atlantic. Women were not allowed on research ships at the time, so Heezen collected sonar data at sea while Tharp stayed onshore, turning the raw data into groundbreaking maps.

Her maps revealed that the Atlantic Ocean floor was not flat, as many had believed. Instead, it was covered with features such as underwater mountains, deep trenches and a 16 000-km mountain ridge. At the centre of this ridge, she discovered a massive crack, or rift, caused by two tectonic plates pulling apart. Tharp suggested this was evidence of continental drift, an idea that was not widely accepted at the time.

FIGURE 6.8 Marie Tharp working on the map of the Atlantic Ocean sea floor in the early 1950s

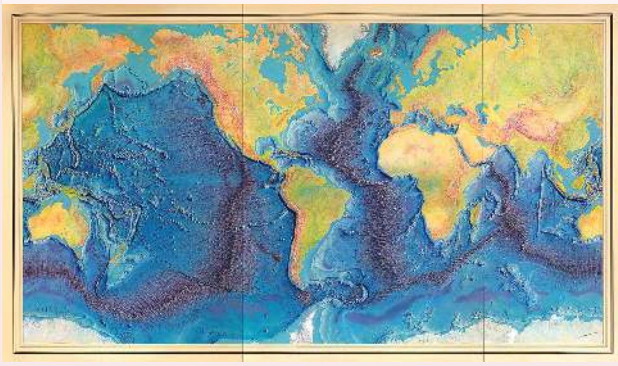
Proving plate tectonics

At first, Tharp's ideas were dismissed as 'girl talk', even by Heezen. But when studies showed earthquakes clustered along her ridge, and Jacques Cousteau's underwater footage confirmed her findings, Tharp's work was undeniable. By the 1960s, her maps and discoveries became key evidence for the theory of **plate tectonics**, which revolutionised how we understand Earth's surface and its movement.

Recognition and legacy

Although Tharp's name was left off many scientific papers, her contributions have since been celebrated. In 1977, she published the first complete map of the world's ocean floors. Today, she is recognised as one of the most important geologists in history, breaking barriers for women in science and changing how we see our planet.

FIGURE 6.9 World Ocean Floor Panorama, 1978. This map by Tharp was painted by Heinrich Berann.



1. What key discovery did Marie Tharp make about the Atlantic Ocean floor, and how did it challenge previous beliefs?
2. How did Tharp's maps provide evidence for the theory of plate tectonics?
3. What challenges did Tharp face as a woman in a male-dominated field, and how did she overcome them?
4. Why was Tharp's work initially dismissed, and what evidence eventually convinced the scientific community of her findings?
5. How did the discovery of the mid-Atlantic ridge and the rift contribute to our understanding of continental drift and plate tectonics?
6. Why is it important to acknowledge the contributions of scientists, like Tharp, who were overlooked in their time?
7. What does Tharp's work demonstrate about how scientific knowledge can change with new evidence?

Scientific knowledge, including models and theories, can change because of new evidence (VC2S8H01)

DISCUSSION

If Earth's size and volume do not change, is there a problem with new crust continually being made at ocean ridges? Formulate an idea or hypothesis that could solve this problem.

6.3.2 How plate tectonics works

The theories of continental drift and sea-floor spreading led to the modern theory of plate tectonics. This theory explains that Earth's lithosphere is broken into large pieces called plates that move over a weaker mantle below, interacting along their plate boundaries.

The theory of plate tectonics is not authored by one person but has evolved through the ideas and discoveries of many (see table 6.3) and continues to evolve today.

TABLE 6.3 Milestones in the development of the theory of plate tectonics

Year	Idea or observation	Who was responsible?
1596	Speculation about Earth's continents having moved	Abraham Ortelius
1858	Maps produced fitting continents together, based on correlation of rock type and fossils	Antonio Snider-Pellegrini
1872–1876	Suggestion of a vast mountain range in the Atlantic Ocean and deep troughs elsewhere, based on 'sounding', a technique that used lead-weighted rope over the side of a ship	*Challenger* expedition, Sir Charles Thomson
1896	Discovery of radioactivity	Henri Becquerel
1912	Theory of continental drift proposed	Alfred Wegner
1925–1927	Sonar surveys identified a mid-ocean ridge in the Atlantic Ocean, continuing to the Indian Ocean	*Meteor* expedition
1927	Convection in mantle proposed to move continents	Arthur Holmes
1928	Zone of earthquakes discovered dipping down from ocean trenches, later recognised to be caused by subducting slabs	Kiyoo Wadati; independently discovered by Hugo Benioff in 1949
1953	Detailed map of the Mid-Atlantic Ridge completed and a central rift proposed	Marie Tharp
1950s–1960s	Theory of the expansion of Earth (later disproved) stimulated development of the idea of sea-floor spreading	Sam W. Carey
1960s	Discovery of the apparent movement of magnetic poles over geological time; this 'polar wander' varied between continents, but came together if the continents were grouped into the supercontinents of Gondwana and Pangaea	Stanley Runcorn, Kenneth Creer and Ted Irving
1961–1962	Proposal that oceanic crust forms along mid-ocean ridges and spreads out laterally away from them; 'spreading ridges' named	Harry Hess and Robert Dietz
1963	Magnetic striping in ocean-floor rocks symmetrical about mid-ocean ridges was used to calculate rates of plate movement	Frederick Vine, Drummond Matthews and Lawrence Morley
1963	Hotspots proposed to explain volcanoes a long way from a plate boundary; transform faults recognised as a third type of plate boundary	John Tuzo-Wilson
1960s	Geophysical evidence gathered, helping define the driving forces of plate tectonics	
1966	The Wilson Cycle was proposed, stating that oceans opened and closed throughout Earth's history	John Tuzo-Wilson

(continued)

TABLE 6.3 Milestones in the development of the theory of plate tectonics *(continued)*

Year	Idea or observation	Who was responsible?
1967	Spherical geometry and Euler's theory of motion on a sphere were used to determine plate motion across divergent boundaries	Jason Morgan and Dan McKenzie
1968	The term 'plate tectonics' was introduced.	Frederick Vine and Harry Hess
1968	Computer model produced of the motion of six plates that form Earth's crust; it showed the total crust created at the ocean ridges equalled the amount lost due to subduction	Xavier Le Pichon
1968	Dating of deep-ocean drill cores showed that the ages of the ocean-floor rocks increase away from mid-ocean ridges	*Glomar Challenger* expedition
1970s	Seismic tomography revealed more of Earth's interior, producing 3D images by combining information from many earthquakes	
1975	Modelling showed that of all the forces likely to be driving plate motion, slab pull is the strongest	Don Forsyth and Seiya Uyeda
1977	First worldwide map of the ocean floor produced	Marie Tharp and Bruce Heezen

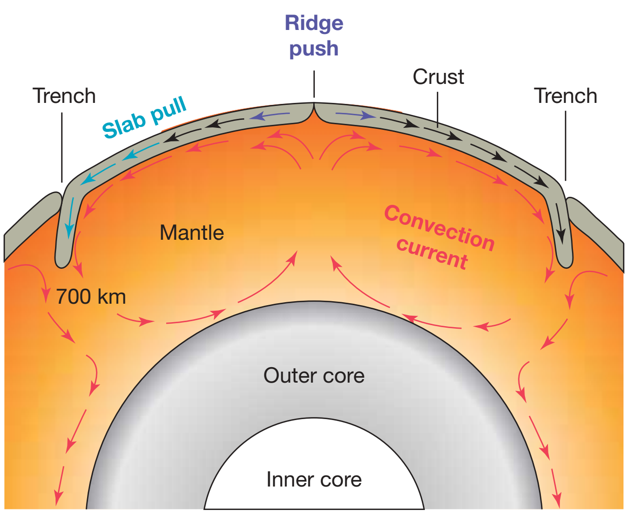
How plates move

Scientists have identified three main forces that drive plate movement:

1. *Mantle* **convection currents**: slow-moving currents in the weaker mantle create friction to help carry the rigid plates above, like items on a conveyor belt.
2. *Slab pull*: When plates collide, the older, colder and denser plate sinks into the mantle beneath the other. This sinking part of the plate acts like an anchor, pulling the rest of the plate with it. Deep-ocean trenches are surface expressions of where this process is happening.
3. *Ridge push*: Newly formed crust at ocean ridges is warm and elevated. Gravity causes this higher crust to push downward and outward, moving crust away from the ridge.

Recent research shows that slab pull is the strongest force driving plates, while ridge push and mantle convection play only minor roles.

FIGURE 6.10 Drivers of tectonic activity

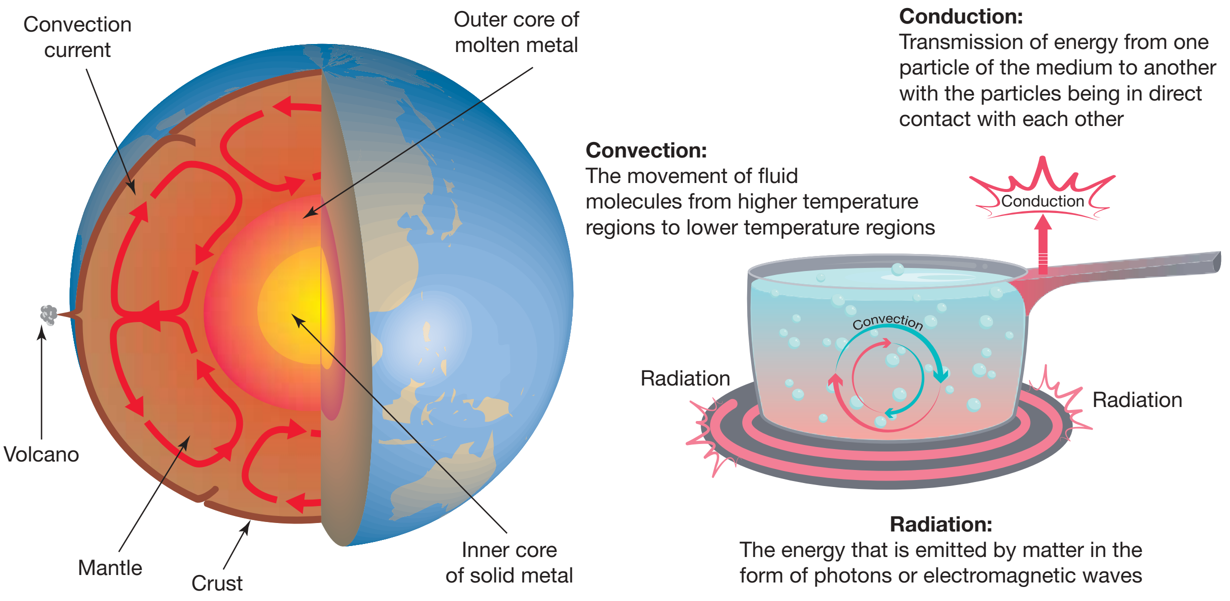


Mantle convection explained

Imagine most of the mantle is like a pot of soup being heated from the bottom. Just like in the soup, parts of the mantle get hotter and rise because heat makes things expand and become lighter. At the top of the mantle, the rock cools and contracts, encouraging it to sink back down under the force of gravity.

This cycle of rising and sinking rock creates mantle convection currents.

FIGURE 6.11 Convection currents in the mantle



INVESTIGATION 6.2

Convection currents

Aim

To observe convection currents

Materials

- 250-mL beaker
- water
- 1 g of potassium permanganate
- Bunsen burner
- tripod
- gauze mat
- matches

Method

1. Set up the Bunsen burner, tripod and gauze mat.
2. Add 200 mL of water into the beaker and heat it until it is boiling.
3. Add 1 g of potassium permanganate and record your observations.

Results

1. Draw a labelled diagram showing your observations.

Discussion

1. What is the purpose of the potassium permanganate in this investigation?
2. Using appropriate scientific terminology, explain your observations.
3. Describe similarities and differences between the convection currents in water and in Earth's mantle.

Conclusion

Summarise your findings from this investigation about convection currents.

Extension

Use a digital thermometer to explore if a temperature difference can be observed in the water at the top of the beaker compared to the bottom of the beaker.

Note: The thermometer should not touch the bottom of the beaker.

6.3 Activities

learnon

6.3 Quick quiz on	6.3 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
2, 3, 4	1, 5, 6	7, 8, 9

Remember and understand

1. **List** the tools used to survey and map the ocean floor during World War II.
2. MC What does the theory of plate tectonics describe?
   A. How Earth's continents float on water
   B. How Earth's lithosphere is divided into moving plates that interact at boundaries
   C. How mountain ranges prevent continental movement
   D. How ocean currents control the movement of landmasses
3. MC Why is oceanic crust more likely to sink into the mantle compared to continental crust?
   A. It is thicker and lighter than continental crust.
   B. It is less affected by mantle convection.
   C. It is denser, allowing it to subduct under continental crust at convergent boundaries.
   D. It is older and therefore more resistant to movement.

Apply and analyse

4. **Identify** three pieces of evidence that support the theory of plate tectonics.
5. The theory of continental drift was first proposed in 1912, over 50 years before the theory of plate tectonics evolved. The evidence for the theory of continental drift also supports the theory of plate tectonics. **Explain** the difference between the two theories.
6. **Explain** why the older ocean floor is found furthest away from the ridge.
7. Marie Tharp's work helped create the first detailed map of the ocean floor, which supported the theory of plate tectonics. **Evaluate** her contribution and **explain** how her discoveries changed scientists' understanding of Earth's surface.
8. Imagine you are a geologist tasked with proving the theory of plate tectonics to someone who doubts it. Design a presentation using key evidence (such as maps and seismic activity data) to convince them the plates are moving.

Evaluate and create

9. Design a visual representation (such as a diagram, infographic or presentation slide) that illustrates the process of sea-floor spreading and how new ocean crust forms and moves over time.

Answers and sample responses are available in your digital formats.

LESSON 6.4 Plate boundaries

LEARNING INTENTION

In this lesson you will describe the different types of plate boundaries and consider Australia's plate tectonic history.

Tectonic plates are made up of continental or oceanic crust (or both). They move only a few centimetres a year (about the speed your fingernail grows). They can collide, move apart or slide past each other.

6.4.1 Plates coming together

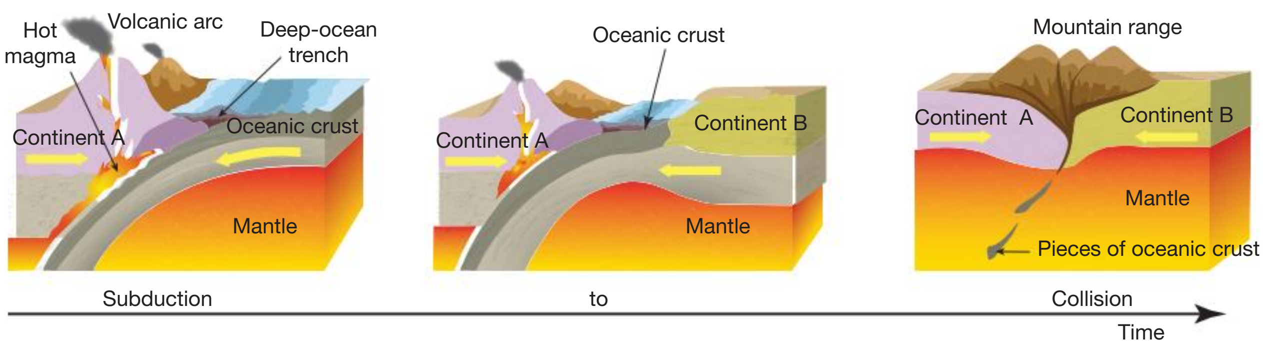
When two tectonic plates move towards each other, they are called converging plates, and the area where they meet is a **convergent boundary**. Two types of convergent boundaries can occur.

1. **Subduction**
   When old oceanic crust moves towards continental crust or younger oceanic crust, the older, heavier crust bends and sinks beneath the other at a **subduction zone**. Subduction zones on the ocean floor are marked by the deep-ocean trenches (figure 6.12, left-hand image).

   Subduction is a destructive boundary where oceanic crust is pushed down into the mantle and transformed into part of the mantle itself. This process generates powerful earthquakes and creates **volcanic arcs** that run parallel to the trenches, such as those found in the Ring of Fire — a well-known region encircling the Pacific Ocean with numerous subduction zones. Over time, subduction can gradually bring two continents closer together, ultimately leading to a collision, as depicted in figure 6.12 (centre image).

2. **Collision**
   When subduction brings two continents together, a collision occurs. Neither continent is heavy enough to sink into the mantle because they are both made of light continental crust. Instead, they crumple together, forming a **mountain range** (figure 6.12, right-hand image). The Himalayan Mountain Range formed from the collision of the Indian Plate and the Eurasian Plate.

FIGURE 6.12 Convergent boundaries from subduction of oceanic crust beneath continental crust through to continent–continent collision, which forms mountain ranges

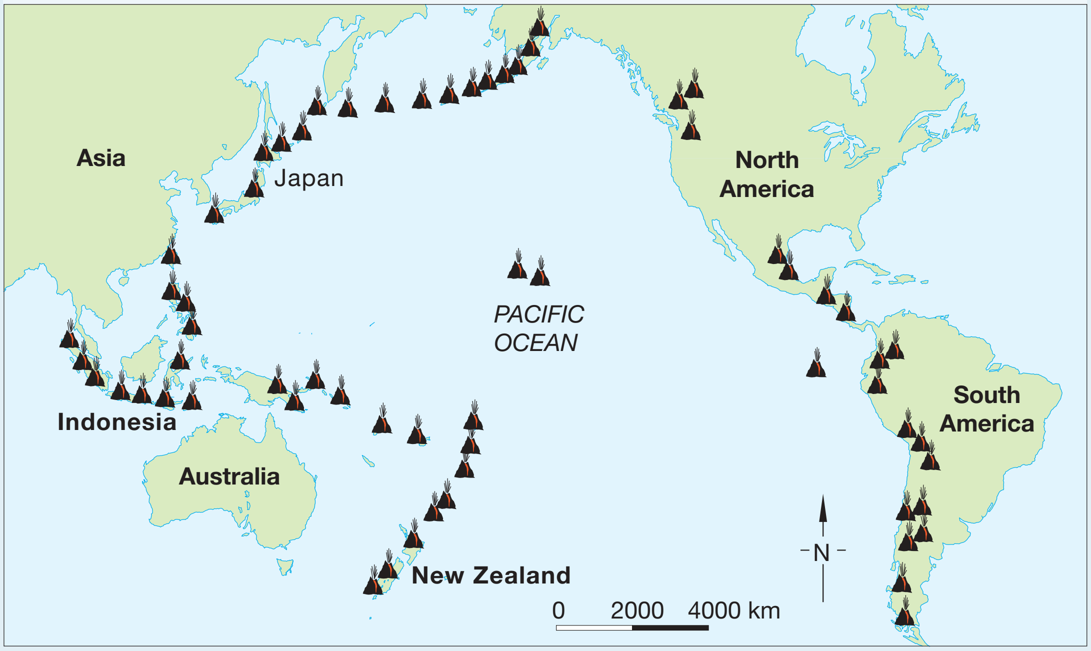


DISCUSSION

The Pacific Ring of Fire

The majority of the world's active volcanoes are not random; they lie along a circle around the Pacific Ocean that is known as the Ring of Fire. Why do you think volcanoes are distributed like this?

FIGURE 6.13 The Ring of Fire



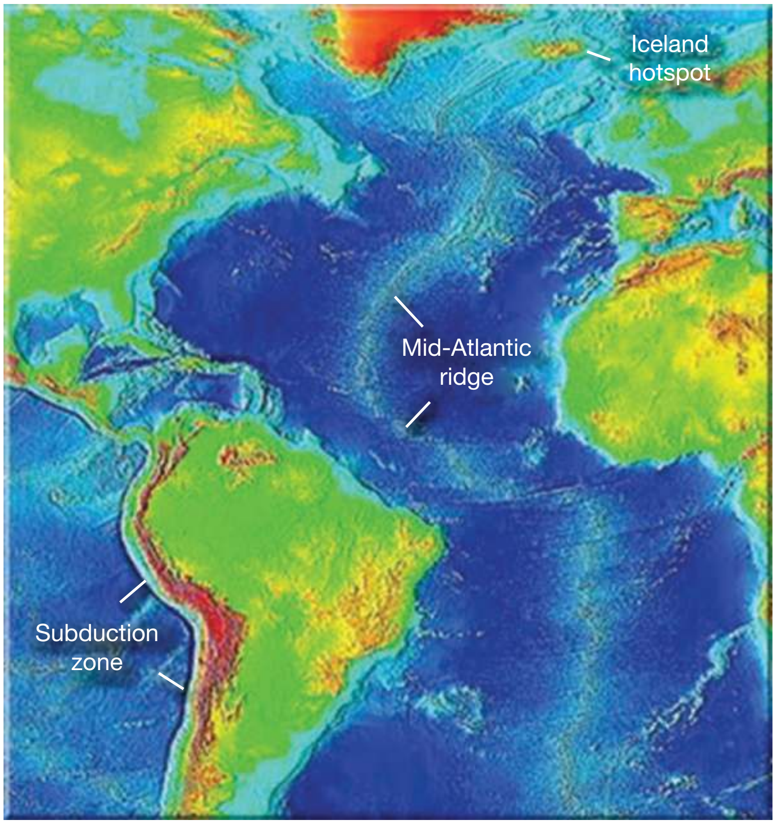
6.4.2 Plates moving apart

A **divergent boundary** occurs where tectonic plates are moving apart. As the plates separate, hot mantle rock rises to fill the gap. The drop in pressure causes the mantle to partially melt — remember, decreasing pressure can drop the melting point — and the molten rock rises to form small volcanoes along the boundary. When the molten rock cools and hardens, it creates new crust. Divergent boundaries are called constructive boundaries because they generate new crust.

FIGURE 6.14 Divergent boundary: sea-floor spreading

One example of a divergent boundary is sea-floor spreading along ocean ridges, where new ocean crust is forming. The Mid-Atlantic Ridge is the largest divergent boundary. It spreads at about 2.5 cm per year, meaning the Atlantic Ocean has been growing for the past 100–200 million years. What started as a small body of water between Europe, Africa and the Americas has become the enormous Atlantic Ocean we know today!

FIGURE 6.15 The Mid-Atlantic Ridge is the largest divergent boundary on Earth.



6.4.3 Plates sliding side by side

When two plates slide past each other, it is called a **transform boundary**, where earthquakes frequently occur. These earthquakes can happen when something blocks the plates from sliding smoothly. Extra pressure builds up until it suddenly releases.

Transform boundaries are also called conservative plate boundaries because no crust is created or destroyed. A well-known example of a transform boundary is the San Andreas Fault in California, USA.

FIGURE 6.16 Transform boundary: plates sliding side by side

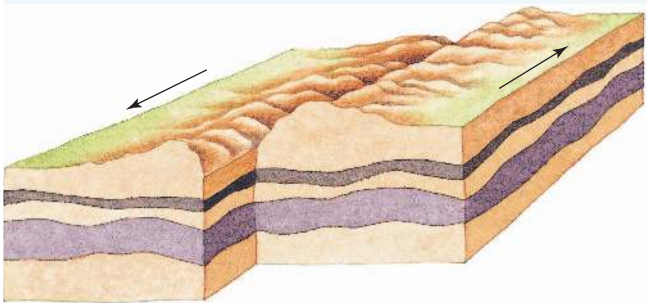
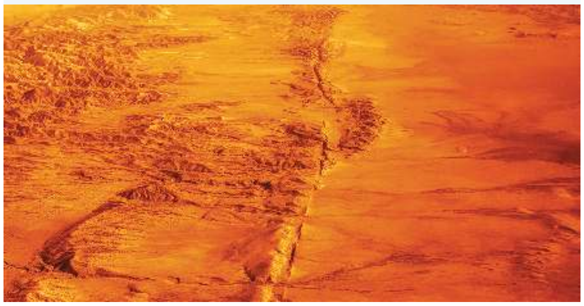


FIGURE 6.17 A view of the San Andreas Fault in California

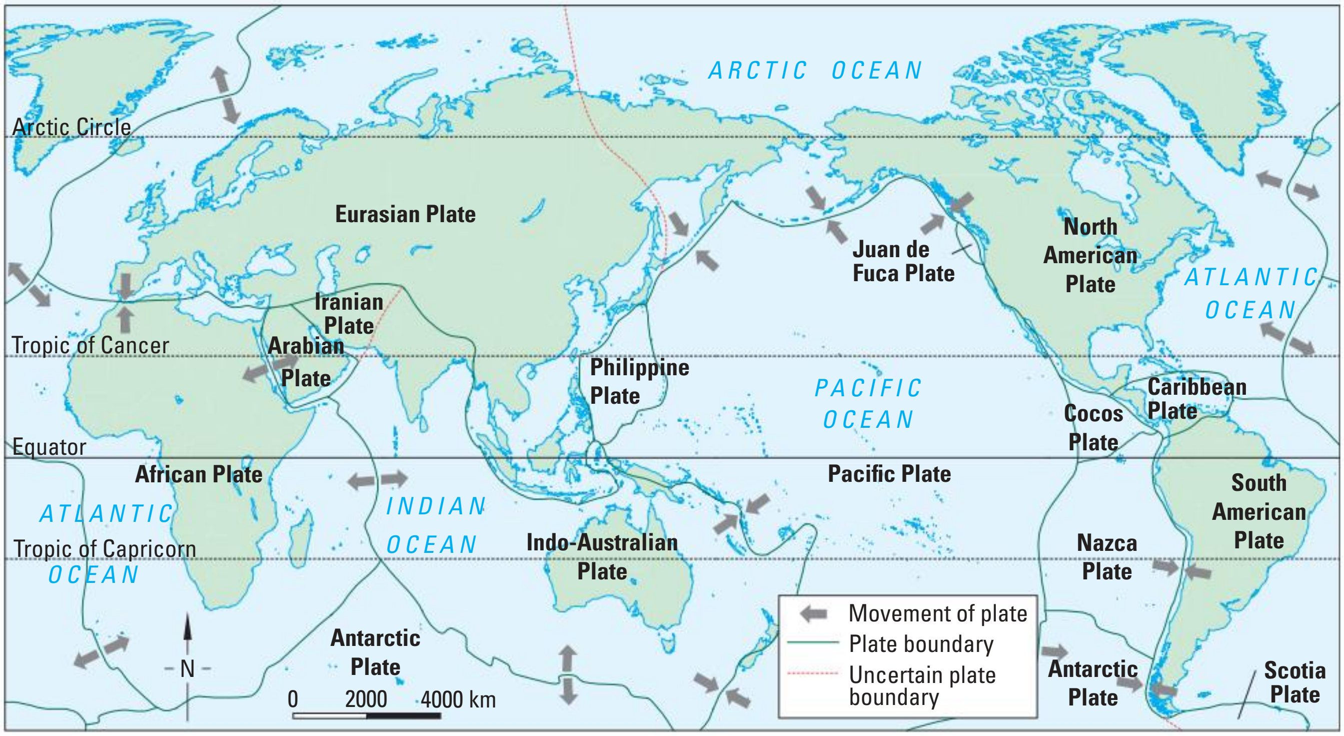


6.4.4 Identifying the current plate boundaries

The major plate boundaries today can be identified by studying patterns of volcanoes, earthquakes, ocean ridges and growing mountain ranges. Geologists have even measured the movement of continents using high-resolution **Global Positioning Systems (GPS)** to confirm where the plate boundaries are located, and the direction the plates are moving.

Earth's crust is not just divided by continents — it is made up of over 20 tectonic plates, some very large and others quite small. Figure 6.18 shows the major plates and the general directions they move. What plate do you live on?

FIGURE 6.18 A simplified map showing the major tectonic plates that make up Earth's crust. The arrows show the direction of plate movement.



6.4.5 Earth recycles itself

The Earth's oceanic crust is constantly being recycled. At ocean ridges, mantle rock rises, partially melts and forms new oceanic crust. As this new crust moves away from the ridge, old crust sinks back into the mantle at subduction zones. This slow process of creating and destroying crust happens over millions of years.

Because of this, ocean basins open and close, and continents shift, grow and reorganise. The continents we see today are not where they were millions of years ago — and they won't stay in the same places in the future.

Reconstructing Earth's past

The theory of plate tectonics has helped geologists reconstruct how continents have moved over time. About 200 million years ago, the supercontinent Pangaea broke apart into two smaller landmasses: **Laurasia** in the north and **Gondwana** in the south. Gondwana included Africa, South America, Antarctica, Australia and India.

Fossil evidence

One famous fossil supporting plate tectonics is *Glossopteris*, a seed fern found across the southern continents of South America, Africa, India, Australia, New Zealand and Antarctica. Glossopteris was the dominant plant in Gondwana for nearly 50 million years.

FIGURE 6.19 Two hundred million years ago Pangaea began to break apart, first into two large masses called Laurasia and Gondwana. Which one was Australia part of?

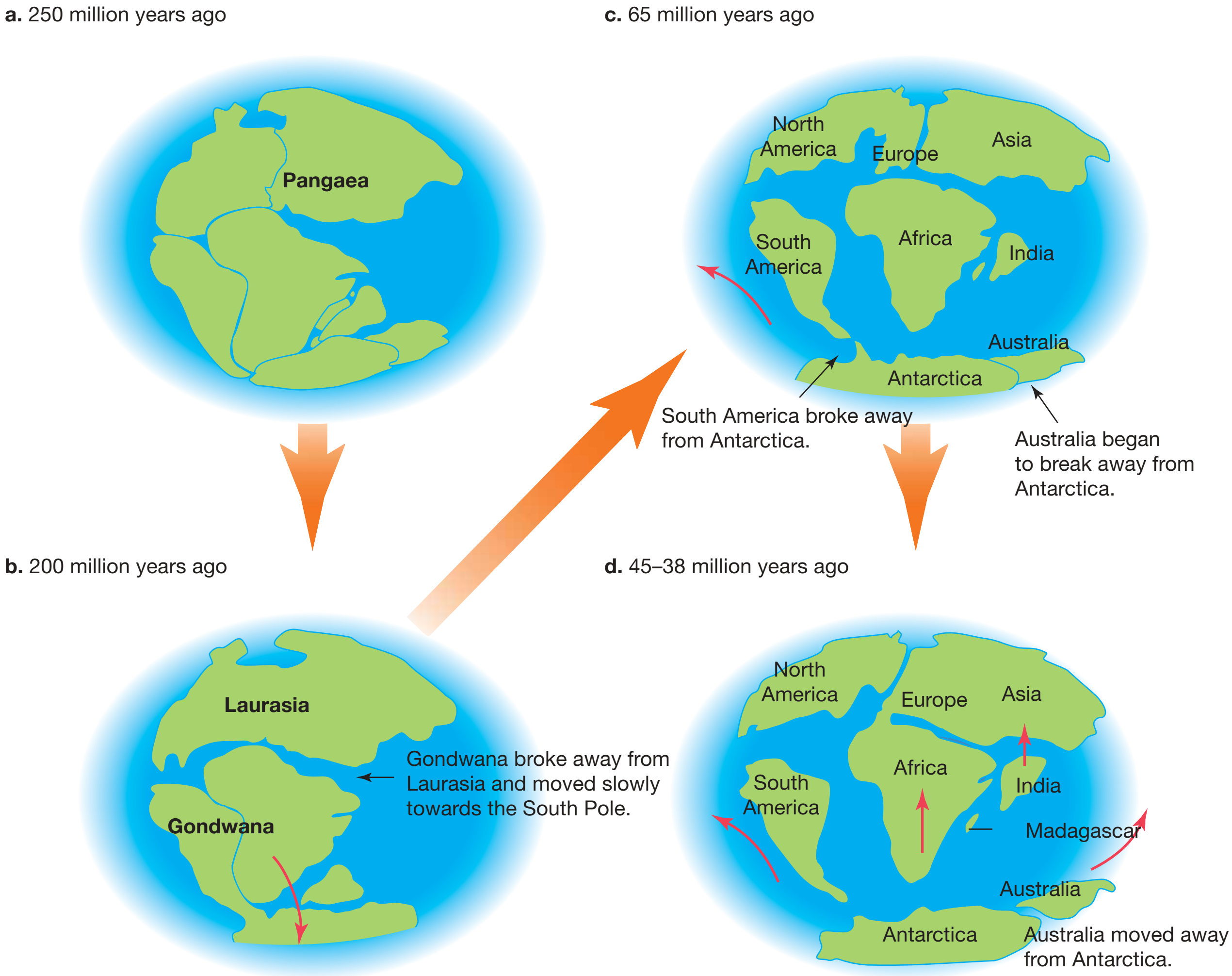


FIGURE 6.20 *Glossopteris* fossils are evidence of the theory of plate tectonics.

CASE STUDY: Australia — An old and stable continent

Australia's geologic history stretches back at least 4 billion years, making it home to some of the oldest minerals and rocks on Earth. Rocks of this age are rare and are only exposed on a couple of other continents: Canada and Africa. Studying Australia's wide range of rocks has provided valuable insights into how continents have evolved over time through plate tectonic movements.

Australia's shape and size have changed throughout its history. It began as smaller pieces of crust that converged and stuck together. Over millions of years, convergence added more continental crust to its edges and, at times, divergence tore it apart — all to become the shape and size we see today.

Its tectonic history tells a story of repeated mountain building and rifting, but today the continent is considered geologically stable. This stability is due to its old, tough continental crust and its location near the centre of a tectonic plate, far from active boundaries where plates interact. As a result, large earthquakes and active volcanoes are rare.

Australia on the move

Although stable, Australia is far from stationary. Using GPS, geologists have measured that Australia is moving north at about 7 cm per year. At this rate, scientists predict it could join with Asia in about 60 million years!

Looking back in time, geologists have found that Australia was once connected to Antarctica. Around 65 million years ago, it began to move northward, separating from Antarctica. As the continent travelled through different climate zones, it experienced dramatic changes: from cold, to cool and wet, to warm and humid, and finally to the hot and dry conditions we see today.

Earthquakes in Australia

Even though Australia is stable, it sits on the Indo-Australian plate, which is slowly colliding with plates to the north (near Indonesia and Papua New Guinea) and east (near New Zealand). These collisions create an internal stress within the plate's interior. The stress is suddenly released when rocks in the upper crust break, causing earthquakes. While large earthquakes are rare, smaller ones can still happen. For example, on 22 October 2023, a magnitude 5.0 earthquake struck near Apollo Bay, Victoria. It was felt in several towns and cities, including Geelong and Melbourne.

6.4 Activities

learnon

6.4 Quick quiz (on)	6.4 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 4	5, 6, 8	7, 9

Remember and understand

1. MC **Identify** where sea-floor spreading occurs.
   A. At subduction zones
   B. At convergent plate margins
   C. Along ocean ridges
   D. From undersea volcanoes
2. **Name** which plate boundary ocean ridges are associated with.
3. **Describe** what happens between plates at the following boundaries.
   a. Transform boundary
   b. Divergent boundary
   c. Convergent boundary — subduction
   d. Convergent boundary — collision
4. What is Gondwana?

Apply and analyse

5. **Explain** why earthquakes are common in the regions surrounding the Himalayas.
6. SI **Explain** what the Ring of Fire is and why, according to the theory of plate tectonics, it exists.
7. The illustration represents part of a plate boundary.

   a. **Identify** the type of boundary present.
   b. **Describe** the movement of the plates on either side of the plate boundary.
   c. Should this boundary be described as a constructive or a destructive boundary? **Explain** your answer.

Evaluate and create

8. SI **Examine** this topographic map of the Indonesian islands and surrounding countries. Focus on the southwestern islands of Sumatra, Java, Bali and Lombok to complete the following.

   a. Trace the arc of volcanoes that form on Sumatra, Java, Bali and Lombok.
   b. Trace the deep-ocean trench in that same area.
   c. There have been several earthquakes recently in this region. **Identify** the type of boundary present that is causing all these earthquakes.
   d. Should this boundary be described as a constructive or a destructive boundary? **Explain** your answer.
   e. Present a hypothesis about the tectonics east of Lombok (around Timor, north of Darwin).
9. **Explain** why the climate of most of the Australian continent has changed from cold to hot and dry during the past 65 million years.

Answers and sample responses are available in your digital formats.

LESSON 6.5 Folding and faulting

LEARNING INTENTION

In this lesson you will understand how tectonic forces from plate movements cause the crust to bend into folds or break into faults, shaping Earth's landscape and triggering earthquakes.

6.5.1 Rocks under pressure

As Earth's plates move, they push, pull, bend and twist solid rock in the crust. The forces are massive — strong enough to break rocks but can also be slow enough to bend them over time. These forces are strongest near plate boundaries but can affect areas farther away too.

FIGURE 6.21 Folded layers of limestone in Thailand that were formed by tectonic forces

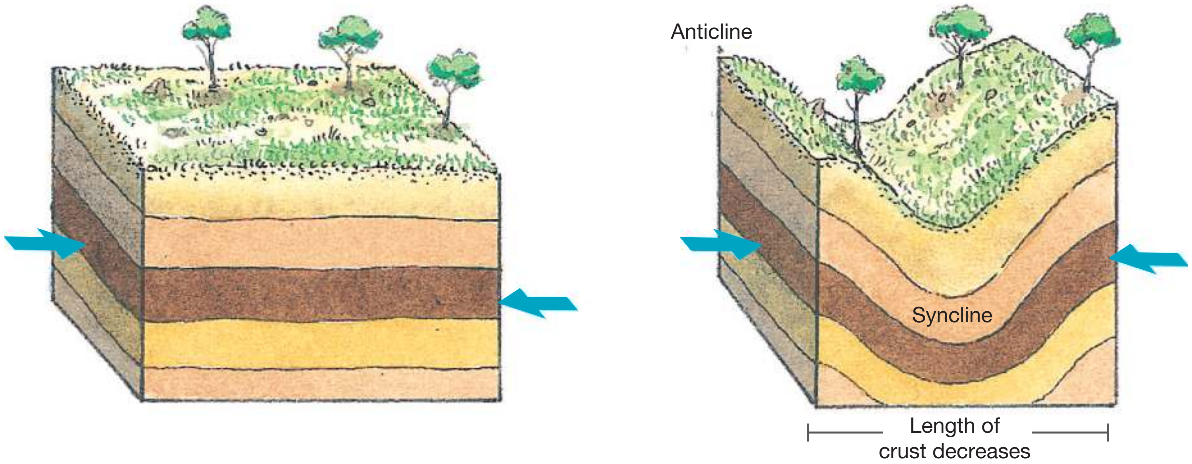
6.5.2 Bending without breaking

Imagine holding a sheet of paper at both ends and gently pushing the ends toward each other. The paper bends upwards or downwards without tearing. In a similar way, the slow, powerful forces from tectonic plate movements can make layers of rock bend and crumple without breaking. The crust crumples best when under **compression** at **convergent boundaries**, and the bent shapes in the rocks are called **folds** (figures 6.21 and 6.22). Most mountain ranges have folded rocks.

- **Anticlines** are folds that bend upwards, forming an 'A' shape.
- **Synclines** are folds that bend downwards, forming a 'V' shape.

These folds usually form deep below Earth's surface and only become visible when they are exposed by uplift and erosion. You are most likely to see folds in road cuttings, river banks or cliffs.

FIGURE 6.22 Applying large and slow forces on solid layers of rock can fold them into anticlines (upward arch) and synclines (downward arch).



CASE STUDY: How did fossils get to the top of the Himalayas?

Did you know that fossils of ancient sea creatures can be found at the top of the Himalayas, thousands of metres above sea level? How did they get there?

FIGURE 6.23 The folding of rocks is important in the creation of the Himalayas, as two parts of Earth's crust collide with each other.

The Himalayas are at a convergent-collision plate boundary where the Indian Plate and the Eurasian Plate are colliding. Geologists believe this collision began about 40 to 50 million years ago. Since both plates are made of continental crust, neither can easily slide under the other. Instead, they are crumpling together, pushing up the land and forming mountains. Sediments that were once at the bottom of the ocean between the two landmasses have been forced upwards and now sit at the peaks of the Himalayas.

The Himalayas are still rising by more than 1 cm per year as the Indian Plate continues to push into Asia. This constant collision causes shallow earthquakes in the region. However, gravitational forces, along with weathering and erosion, wear the mountains down at about the same rate. That's why mountains such as Mount Everest, which is about 8840 m above sea level, do not grow much taller.

INVESTIGATION 6.3

Modelling folds

Rocks are usually folded well below Earth's surface. The anticlines and synclines can be seen only along road cuttings or where erosion has exposed the layers of rock. A model is a useful way to describe how folded rocks would appear under the surface.

Aim

To model the folding of rocks

Materials

- 3 or 4 pieces of differently coloured plasticine
- ruler
- knife or blade or dental floss
- rolling pin
- board

Method

1. Using the rolling pin, roll the individual colours of plasticine into 0.5–1 cm thick layers.
2. Stack the layers of coloured plasticine on top of each other. Press down lightly on the layers, so that they stick together, but not too much as to cause the plasticine to stick to the table.
3. Measure the length and thickness of your model.
4. With the palms of your hands or books on opposite ends, very gently compress the layers from the side by bringing your hands (or books) closer to each other.
5. Measure the new length and thickness of your model.

Results

1. Describe the appearance of the plasticine when the layers are compressed. Include the measure of length and thickness change.
2. Draw a diagram of the plasticine after compression, labelling anticlines and synclines (don't forget a scale).

Discussion

1. Discuss the relationship between the change in length and the change in thickness. Include a link to building a mountain range.
2. Consider why rocks need to be compressed slowly (or gently) to form folds.

Conclusion

Summarise the findings from this investigation about modelling folds.

Extension

Imagine that the rock layers are eroded at Earth's surface. With the tools provided, model erosion and draw a set of new diagrams of the eroded model, as viewed from above and when viewed from the side.

Where are the oldest and youngest rocks? (Recall the relative age of rock layers with older layers deposited first.) Is there any relationship between the geometry of anticlines or synclines and the age of rocks?

6.5.3 Breaking under stress

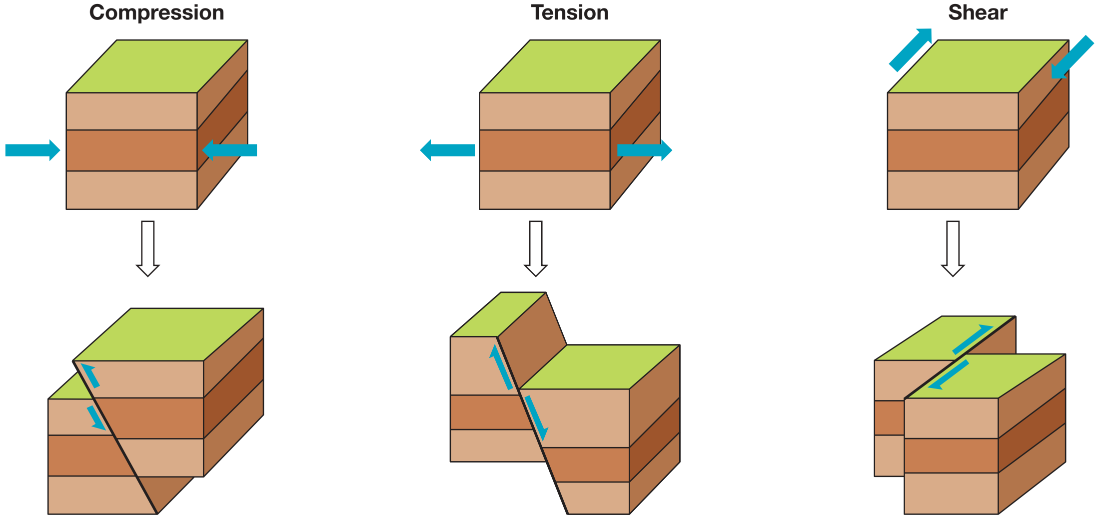
While slow tectonic movements create folds, faster or stronger forces closer to the surface can cause rocks to break instead of bend. This creates **faults**. Different types of tectonic forces produce different kinds of faults (table 6.4 and figure 6.24).

TABLE 6.4 Types of tectonic forces and types of faults

Type of plate boundary	Type of tectonic force	Types of fault
Convergent	Compression: Plates push rocks together.	Reverse faults: Rocks are pushed together, and one block moves up.
Divergent	**Tension**: Plates pull rocks apart.	Normal faults: Rocks are pulled apart, and one block moves down.
Transform	**Shearing**: Plates slide rocks past each other.	**Strike-slip faults**: Rocks slide past each other horizontally.

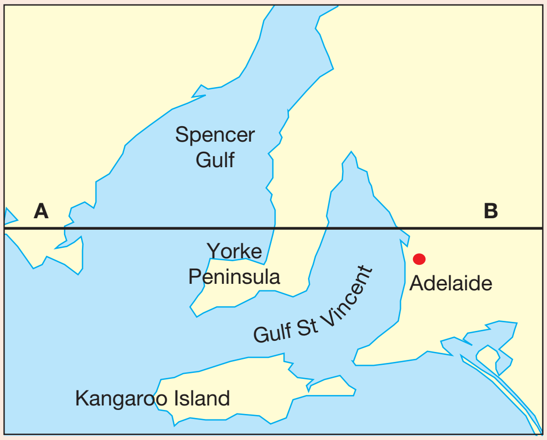
Sometimes faults involve both vertical and horizontal movement, making them more complex. When rocks move along a fault, the movement happens quickly and produces earthquakes.

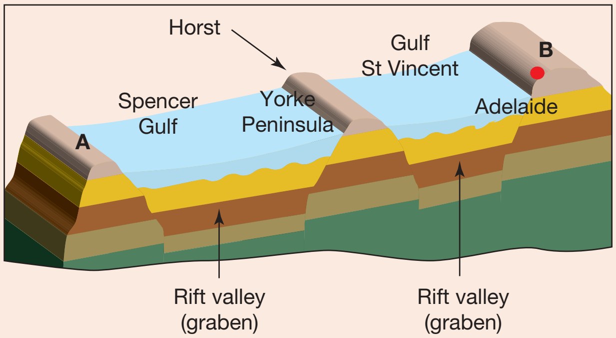
FIGURE 6.24 Compression, tension and shear are different forces. Each produces different types of faults.



CASE STUDY: Forming valleys and mountains in South Australia

FIGURE 6.25 Faulting has shaped the Gulf region of South Australia.





The Gulf region of South Australia has been shaped by a series of **normal faults**. Two blocks of crust have dropped down between faults to form Spencer Gulf and Gulf St Vincent. These sunken blocks are called **rift valleys** or grabens. Between them is a block that is kept at a higher elevation than the rift valleys. This block, called a **horst**, has formed the Yorke Peninsula.

What type of force do you think causes horsts and grabens to form?

Occasionally, earthquakes are felt in the Adelaide area from movement along these faults, but the movement has changed from when the current landscape was formed. Recent earthquakes are the result of compression, which has changed the normal faults into **reverse faults**!

INVESTIGATION 6.4

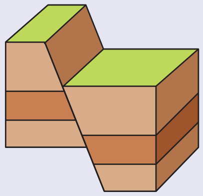
Modelling faults

Aim

To model normal and reverse faults

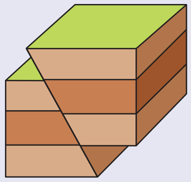
Materials

- 3 or 4 pieces of differently coloured plasticine
- a thin sheet of polystyrene
- knife or blade



Method

1. Place the first piece of plasticine on the bench and flatten it into a rectangular shape. Do not make it too thin. Cut a piece of polystyrene the same size and fit it over the plasticine rectangle.
2. Add two or three more layers of plasticine with a layer of polystyrene between each layer.
3. Cut through the layers at an angle as shown in the diagram. Use the two parts to model each of the two types of faults shown.



Results

Photograph or draw a diagram of each fault. Label it with arrows to show the direction in which each block moved to create the fault.

Discuss

1. Which fault type would you expect to find in the Himalaya mountains? Why?
2. Which fault type would you expect to find along the oceanic ridges? Why?
3. Propose a method for demonstrating and creating a model for a strike-slip fault.

Conclusion

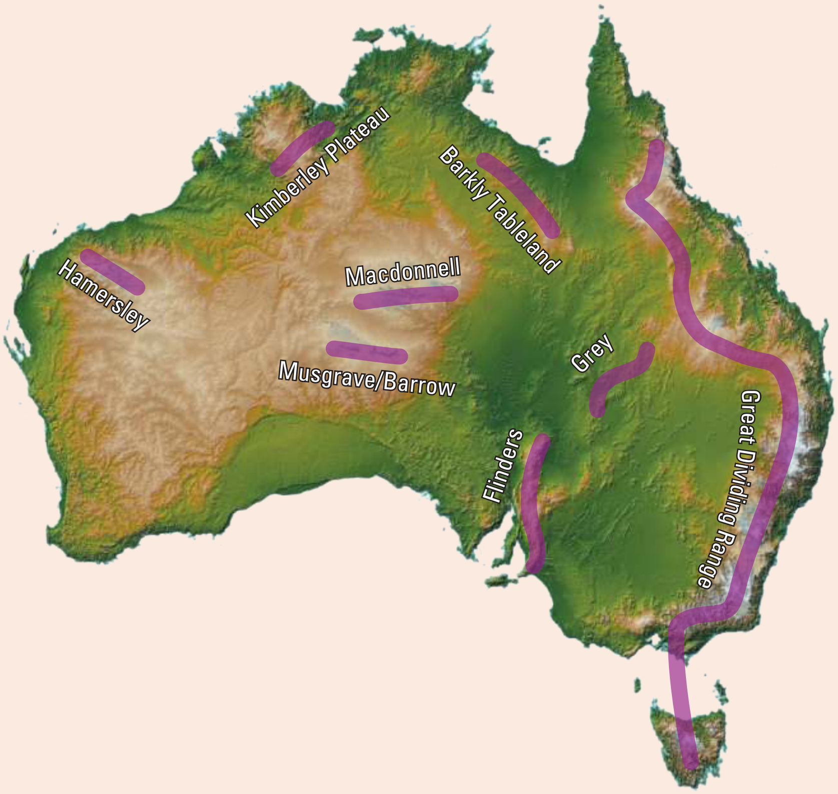
Summarise the findings for this investigation about modelling faults.

CASE STUDY: The great dividing range

Australia's Great Dividing Range stretches all the way from northern Queensland to Tasmania. It is actually a chain of separate mountain ranges, including the Carnarvon Range in central Queensland, the Blue Mountains of New South Wales, the Australian Alps, the Dandenong Ranges near Melbourne and the Central Highlands of Tasmania.

About 80 million years ago, the Tasman Sea between Australia and New Zealand began to open by sea-floor spreading as Gondwana was splitting apart. The western edge of this rift basin was uplifted to form the Great Dividing Range. Several volcanoes were active along it, erupting large volumes of material that included diamonds and sapphires!

FIGURE 6.26 Australia's Great Dividing Range is the longest mountain range in Australia.



6.5 Activities

learnon

6.5 Quick quiz	6.5 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 4, 6	3, 5, 7, 10	8, 9, 11

Remember and understand

1. **Explain** why rocks would bend or break.
2. MC When referring to layers of rock, what is *folding*?
   A. The bending and crumpling of rock without breaking
   B. The breaking and crumpling of rock
   C. The uplifting of super-cooled magma to create rock
   D. The uplifting of rock along a fault
3. **Explain** the cause of folding.

4. **Name** the three different types of forces responsible for developing different fault movements.

Apply and analyse

5. **Compare** syncline and an anticline.
6. a. **Explain** the difference between a reverse fault and a normal fault.
   b. Sketch a reverse fault and a normal fault.
7. **Explain** what causes earthquakes along the San Andreas Fault.
8. SI There is a lot of faulting as well as folding in the Himalayas. **Explain** how it is possible for both folding and reverse faulting to develop during mountain building.
9. When the Tasman Sea started forming around 80 million years ago, the Great Dividing Range experienced uplift and faulting. What type of faults would you predict dominated this event?

Evaluate and create

10. SI **Explain**, with the aid of labelled diagrams, how mountains could be formed by faulting.
11. SI **Discuss** why mountains do not grow forever. Use Mount Everest as an example.

Answers and sample responses are available in your digital formats.

LESSON 6.6 Earthquakes

LEARNING INTENTION

In this lesson you will:
- explain how earthquake waves move
- outline methods used to measure them
- evaluate their potential dangers.

6.6.1 Shake, rattle and roll

Earthquakes happen when rocks in Earth's crust move along faults. Rocks can stretch and bend under pressure, but only up to a point — like a rubber band snapping when stretched too far. When the rocks snap and shift, they release energy, causing the ground to shake.

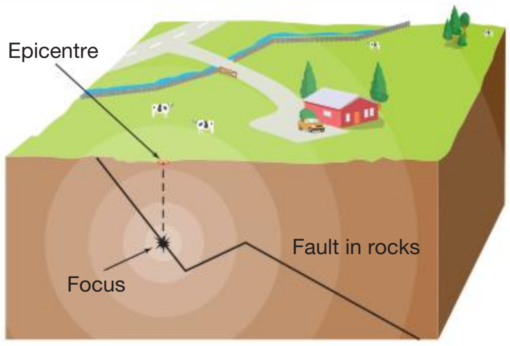
Most ground vibrations are too weak to feel and are called **tremors**. When the vibrations are strong enough to feel, they are called earthquakes.

The focus of an earthquake is the point deep in the Earth where the earthquake starts. The **epicentre** is the point on the surface directly above the focus.

Tremors and minor earthquakes can take place wherever there is a fault or weakness in the Earth's upper crust. However, major earthquakes generally occur at or near the plate boundaries, where plates are:

- pushing against each other in subduction zones or collisions
- spreading apart at rift valleys or ocean ridges
- sliding past each other, such as at transform boundaries

FIGURE 6.27 An earthquake in Earth's crust.



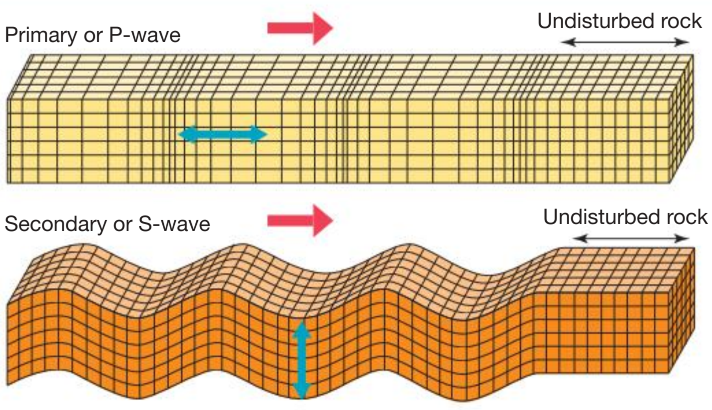
KEY IDEA

The epicentre of an earthquake usually experiences the strongest shaking, but if the focus is more than 20 km deep, the vibrations have further to travel and will result in weaker shaking at the surface.

6.6.2 Seismic waves

When an earthquake occurs, energy is released in the form of seismic waves. These waves are divided into two main groups: **body waves** and **surface waves**.

FIGURE 6.28 P-waves travel through Earth as compression waves, while S-waves are transverse waves.



Body waves

Body waves travel outward through Earth's interior.

- **P-waves** (**primary waves**) are compression waves with a push-and-pull motion, like sound waves through air. They are the fastest and can travel through all of Earth's interior layers.
- **S-waves** (**secondary waves**) travel in the form of transverse waves with an up-and-down motion. They are slower than P-waves and cannot travel through liquids. Scientists have reasoned that the outer core is liquid because no S-waves have been observed to travel through it.

Surface waves

Surface waves only travel along the Earth's surface and are the slowest seismic waves. They also lose energy as they travel farther or deeper.

- **Love waves** (or L-waves) move in a side-to-side motion, like a snake slithering.
- **Rayleigh waves** move with a rolling motion, like an ocean wave.

Surface waves cause the most damage during an earthquake because their energy is concentrated on the surface, unlike body waves, which spread out through Earth's interior.

FIGURE 6.29 L-waves travel along the surface with a side-to-side motion, while Rayleigh waves have a rolling motion.

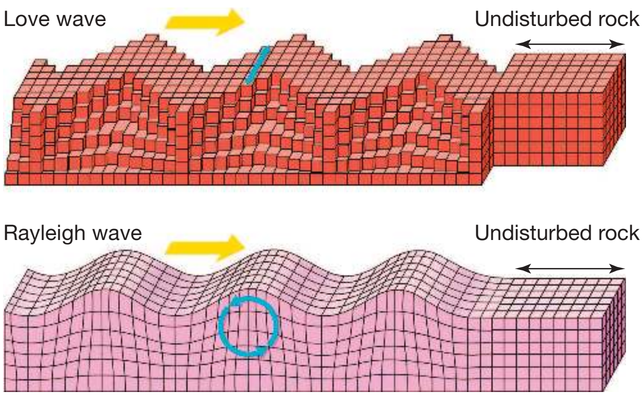
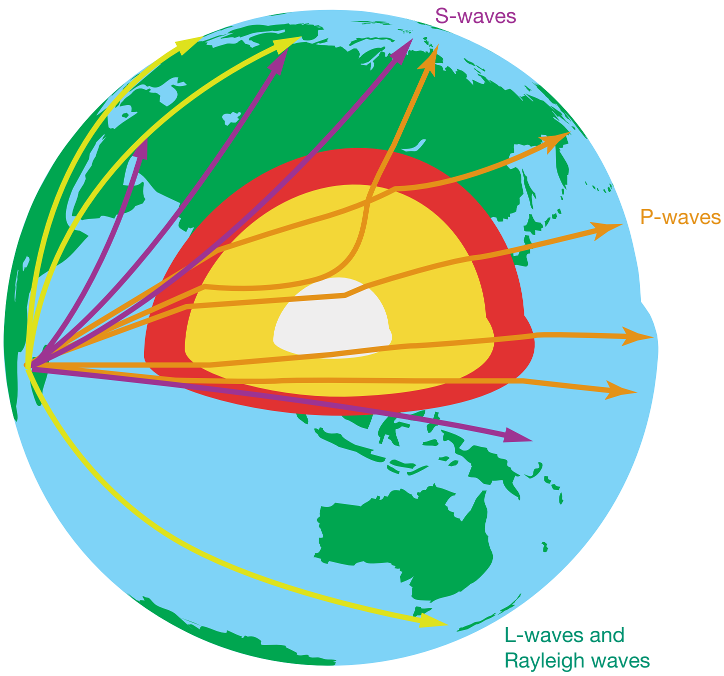


FIGURE 6.30 P-waves are able to travel through all of Earth's interior; S-waves cannot travel through liquid, and are thus not observed in the outer core; L-waves and Rayleigh waves will only travel along Earth's surface.



6.6.3 Measuring earthquakes

Movements in Earth's crust are recorded with a **seismograph** (or seismometer). Older seismographs used a strip of paper that moved past a stationary pen to record the vibrations (figure 6.31). Today, seismographs use electrical currents to create digital graphs of earthquake activity (figure 6.32).

Seismographs record the different types of seismic waves. The waves show up as separate groups on the graph because they travel at different speeds. The further apart the waves are, the farther the seismograph is from the earthquake's epicentre. Also, the peaks of the waves are shorter if the seismograph is farther from the epicentre, because the earthquake loses energy the further it travels.

FIGURE 6.31 An earthquake recorded on a seismograph

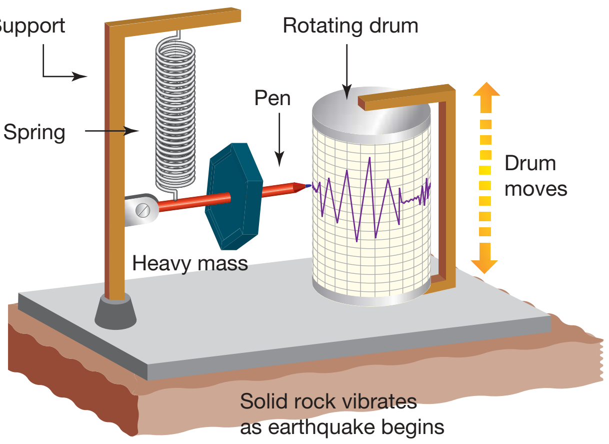
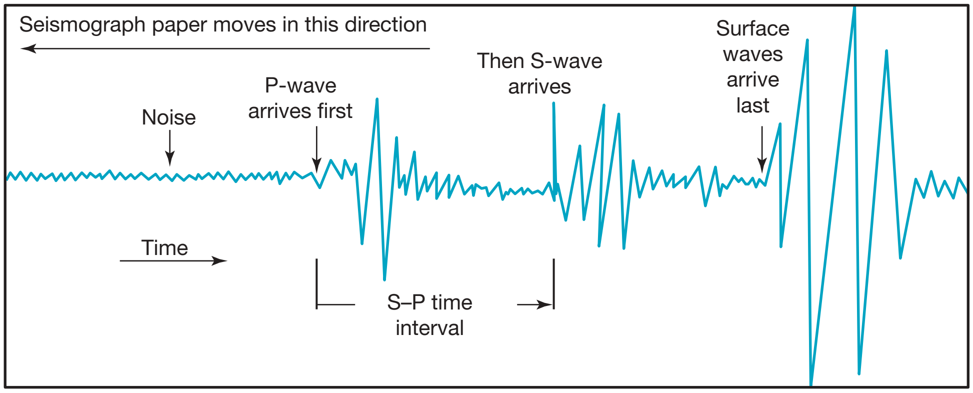


FIGURE 6.32 Different types of waves travel at different speeds, which allows scientists to tell how far away the earthquake is.



INVESTIGATION 6.5

Aim

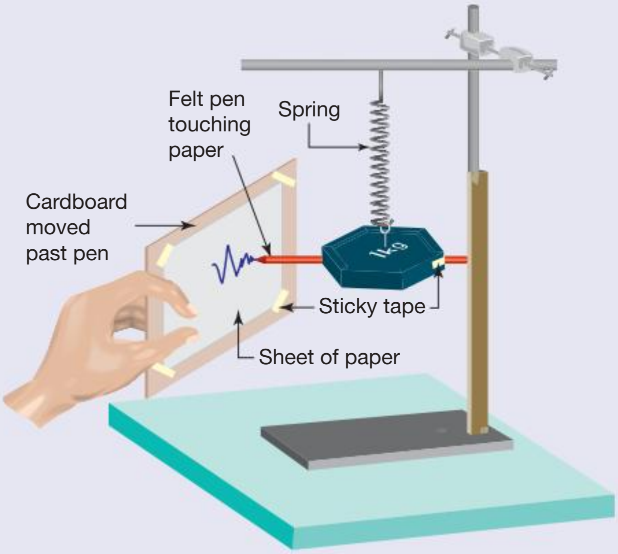
To construct a working model of a seismograph

Materials

- retort stand, bosshead and rod
- spring
- cardboard
- 500-g or 1-kg weight (or a can full of sand)
- sticky tape
- felt pen
- A4 paper

Method

1. Set up the equipment as shown in the diagram.
   Note: a cardboard guide can be made to sit either side of the pen so there is no sideway motion.
2. Pull down on the spring, then release it. Have your partner slide the cardboard past the pen (keeping the board in contact with the table the entire time).
3. Repeat step 2 with a new piece of paper, pulling down on the spring less than in step 2.



Results

1. Title and present your seismograph records.
2. Label where the 'earthquake' is on the records.

Discuss

1. Describe how the model works and how it could be improved.
2. Discuss the difference between the record of pulling down the spring less and more. How would that difference affect the validity of evaluating the Richter magnitude from just one seismograph?

Conclusion

Summarise the findings for this investigation about the model of a seismograph.

The Richter scale

The **Richter scale** is a measure for earthquake magnitude (strength). It was developed by Charles Richter and others in 1935. According to the Richter scale, the strength of an earthquake is determined by the amplitude (height) of the waves recorded by seismographs.

The Richter scale ranges from 0 to 10, and each increase of 1.0 means the earthquake releases **30 times more energy**.

For example:
- A magnitude 6.0 earthquake releases 30 times more energy than one with a 5.0 magnitude.
- A magnitude 7.0 earthquake releases 900 times (30 × 30) more energy than one with a 5.0 magnitude.

SCIENCE INQUIRY: Earthquake magnitudes

Aim

Formulate a hypothesis relating the strength of an earthquake to the resulting damage

Over 400 earthquakes are recorded every year on the University of Melbourne's high-precision seismic network. The majority have a magnitude of less than 3.5. The largest earthquake recorded in Victoria was one measuring 5.9, which hit near the town of Rawson on 22 September 2021.

For comparison:
- Microquakes (magnitude less than 2.0) are rarely felt by humans.
- Earthquakes of magnitude 4.0 can rattle objects and be felt by people.
- The largest earthquake ever recorded was a magnitude 9.5 in southern Chile in May 1960.

Think about how earthquake magnitudes might relate to the level of damage they cause.

Task

1. Construct an investigable hypothesis that relates earthquake magnitude to the resulting damage.
2. Research reports of earthquakes with different magnitudes and note the level of destruction for each. Consider factors like:
   - magnitude of the earthquake
   - whether the area was urban or rural
   - building designs and preparation for earthquakes.

Question

Does your hypothesis hold up after investigating the evidence?

Investigable questions, reasoned predictions and hypotheses can be developed in guiding investigations to identify patterns, test relationships and analyse and evaluate scientific models (VC2S8I01)

6.6.4 Destructive power

Even though Australia is not on the edge of a tectonic plate boundary, it still experiences earthquakes. They are caused by compression within the Indo-Australian Plate, coming from its convergent boundaries in the north and east. This compression builds up inside the plate and is released as earthquakes. On average, 100 earthquakes of magnitude 3.0 or higher occur in Australia each year.

The amount of destruction caused by an earthquake depends on several factors, including:

- earthquake magnitude
- distance from epicentre
- size of population
- type of building materials
- ground type (soft ground can amplify shaking).

FIGURE 6.33 In February 2023, a magnitude 7.8 earthquake struck Turkey and Syria. The earthquake killed more than 50 000 people.

DISCUSSION

Tennant Creek, Northern Territory (1988)

A magnitude 6.6 earthquake caused only minor damage to two buildings and a gas pipeline 40 km north of the epicentre.

Newcastle, New South Wales (1989)

A magnitude 5.6 earthquake killed 13 people, injured 160 and destroyed 300 buildings. The epicentre was 15 km southwest of the city’s CBD.

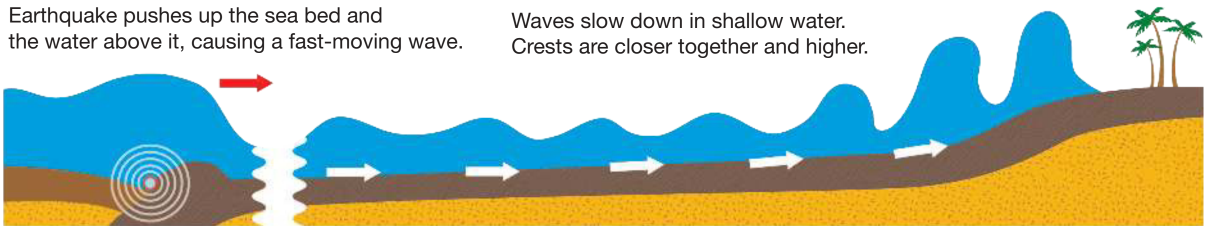
Using the Tennant Creek and Newcastle earthquake examples, discuss what factors influenced the level of destruction.

6.6.5 Waves of destruction

Earthquakes under the ocean or near the coast can create giant waves called **tsunamis**. These waves form when an underwater fault moves, pushing up the sea floor and the water above it. This movement creates powerful waves that can travel through the ocean at speeds of up to 900 km/h.

As the waves reach shallower water near the coast, they slow down but grow much taller, sometimes reaching heights of 30 m. These massive waves can cause widespread destruction when they reach land.

FIGURE 6.34 Illustration of how a tsunami forms



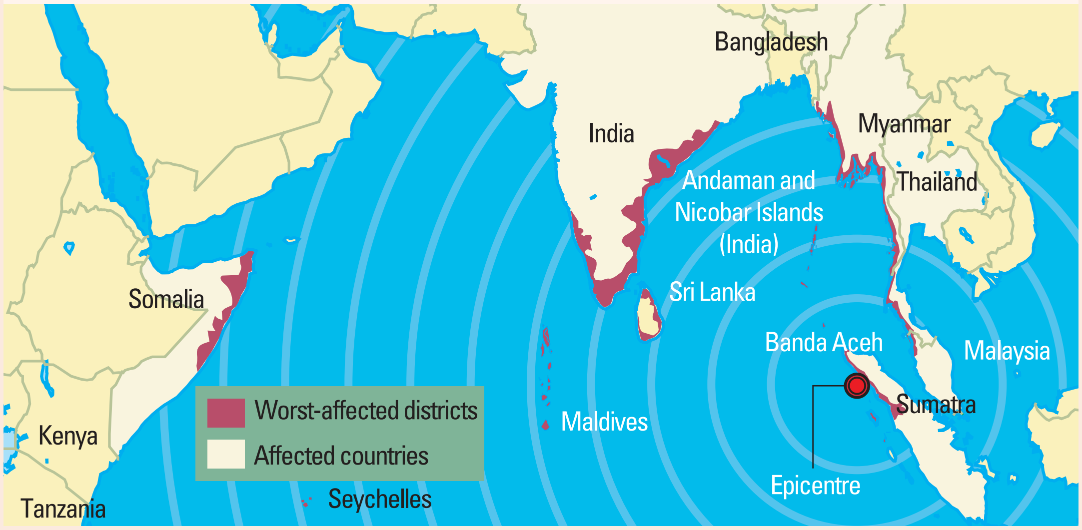
CASE STUDY: The 2004 Sumatra–Andaman Tsunami

The devastating power of tsunamis became tragically clear on 26 December 2004. A massive earthquake under the ocean floor, about 250 km off the coast of Sumatra, caused a tsunami that killed approximately 300 000 people across South-East Asia, southern Asia and eastern Africa. Millions more lost their homes.

The earthquake, with a magnitude of 9.0, lifted a 1000-km-long strip of the ocean floor by 30 m, triggering the tsunami. Near Banda Aceh in Sumatra, Indonesia, the tsunami flooded up to 10 km inland with a 3-m-high wall of water, mud and debris. Thousands more were killed in Sri Lanka, India and Thailand, with further deaths in Malaysia, Myanmar, Bangladesh and the Maldives.

Even 8 hours later, the tsunami reached Africa's east coast, over 5000 km away, causing flooding and killing more than 160 people in Somalia, Kenya and Tanzania.

FIGURE 6.35 This map shows the huge area affected by the Sumatra–Andaman tsunami on 26 December 2004.



SCIENCE AS A HUMAN ENDEAVOUR: Living on the edge

For the people living near the plate boundaries, particularly along the Pacific Ocean's Ring of Fire, the ability of scientists to predict earthquakes and tsunamis is critical. The scientists who study earthquakes are called **seismologists**, and they use various methods to understand and anticipate these natural events.

Although it is difficult to predict the time, location and size of earthquakes, seismologists use:
- patterns of past earthquake events to identify the probability of earthquakes of different sizes
- sensors to monitor movement and pressure build-up along plate boundaries and fault lines.

Predicting earthquakes

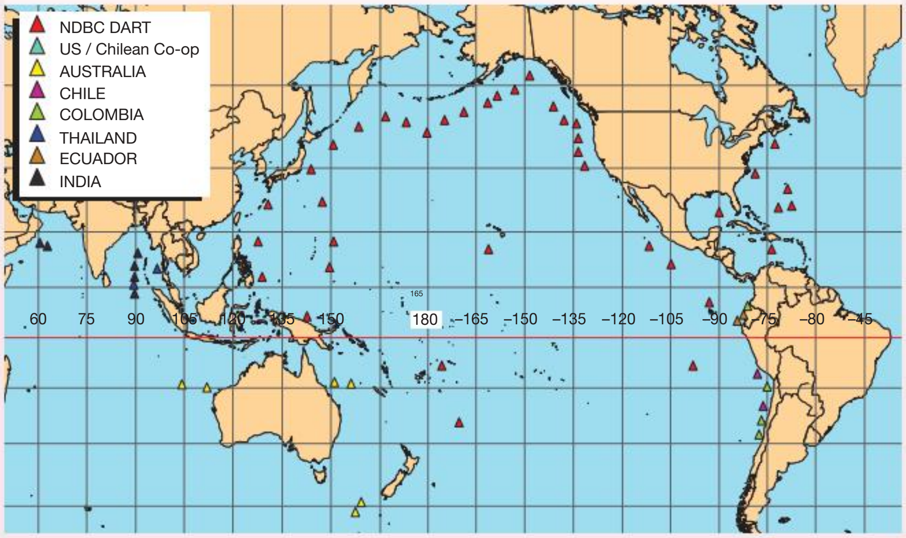
Accurately predicting the exact time, location and magnitude of earthquakes remains a significant challenge. However, seismologists utilise the following.
- *Historical patterns*: analysing past earthquake occurrences to estimate the probability of future events in specific regions.
- *Monitoring systems*: deploying sensors to detect movements and stress accumulation along fault lines and plate boundaries.

While precise predictions are not yet possible, these methods help assess earthquake risks and inform preparedness strategies.

Tsunami early warning systems

Since powerful earthquakes can trigger tsunamis, scientists also focus on early warning systems that help coastal communities prepare for these devastating waves. Tsunami warning systems are vital for coastal communities. One such system is the Deep-ocean Assessment and Reporting of Tsunamis (DART®), which consists of strategically placed buoys that detect sea level changes indicative of tsunamis. These buoys transmit real-time data to warning centres, enabling timely alerts and evacuations.

FIGURE 6.36 The locations of DART buoys



1. Why is it challenging for seismologists to predict the exact timing and location of earthquakes?
2. How do historical earthquake patterns assist in assessing future earthquake risks?
3. What role do monitoring systems play in earthquake preparedness?
4. How does the DART® system contribute to tsunami early warning capabilities?
5. Why is international collaboration important in monitoring and responding to seismic events?

Proposed scientific responses to socio-scientific issues impact on society and may involve ethical, environmental, social and economic considerations (VC2S8H03)

SCIENCE AS A HUMAN ENDEAVOUR: Monitoring earthquakes in Australia and beyond

Geoscience Australia monitors seismic activity 24/7 using data from over 150 stations in Australia and more than 500 stations worldwide. Within 30 seconds, most data from seismometers are sent to their central processing facility in Canberra through digital satellite and broadband systems.

Geoscience Australia also works with other countries, using seismic data from New Zealand, Indonesia, Malaysia, Singapore, China and global networks from countries such as the United States of America, Japan, Germany and France. Data from the International Monitoring System is also used, especially for tsunami warnings.

How earthquakes are analysed

The seismic data are analysed automatically and reviewed by seismologists at Geoscience Australia. They play a key role in tsunami warnings as part of a warning centre. For earthquakes that might cause tsunamis, the seismologists report within 10 minutes of the earthquake's origin time. Alerts are then sent to the Bureau of Meteorology, which provides tsunami advice and warnings.

For other earthquakes with magnitudes greater than 3.5, their details — magnitude, origin time, date and location — are calculated within 20 minutes.

Why would quick reporting be so important?

FIGURE 6.37 Geoscience Australia's National Earthquake Alerts Centre

Source: © Commonwealth of Australia (Geoscience Australia) 2021

1. Why is it important for Geoscience Australia to collect and analyse seismic data from both local and international stations?
2. How does the data from seismometers contribute to tsunami warnings?
3. Why is it critical for seismologists to report within 10 minutes of an earthquake that might cause a tsunami? What might happen if warnings are delayed?
4. For earthquakes with a magnitude greater than 3.5, how does providing timely information benefit communities and governments?
5. How does collaboration with other countries and international networks enhance Geoscience Australia's ability to monitor seismic activity?
6. What are the ethical and social considerations involved in ensuring accurate and timely earthquake reporting?
7. How might technological advancements improve earthquake and tsunami monitoring systems in the future?
8. In what ways could quick and accurate seismic reporting save lives and minimise damage during a natural disaster?

Proposed scientific responses to socio-scientific issues impact on society and may involve ethical, environmental, social and economic considerations (VC2S8H03)

SCIENCE INQUIRY: Build an earthquake-proof office block

Earthquakes release built-up pressure in the Earth's crust, shaking the ground. However, the size of an earthquake (its magnitude) is not the only factor that determines how destructive or fatal it will be in an urban setting. The number of people nearby and the quality of the affected buildings, houses and other structures are the most important factors. Poorly built structures often collapse, causing the most deaths during earthquakes.

Although continental Australia does not sit on a plate boundary, earthquakes can still happen. For example, the 1989 Newcastle earthquake (magnitude 5.6) caused 13 deaths and damaged over 60 000 buildings, and a magnitude 5.9 earthquake occurred near Mansfield in Victoria in 2021, causing damage to buildings as far away as Melbourne, leaving one person injured. That is why building safer structures is important.

FIGURE 6.38 Damaged buildings on Melbourne's Chapel Street, caused by an earthquake with an epicentre near Mansfield, Victoria. Tremors were felt as far away as Canberra, Sydney and Tasmania.

Task

Your company, Shakeless Seismic Solutions, has been asked by a wealthy client to design an earthquake-proof, five-storey office block in Melbourne. To win the contract, your team must complete the following.

1. Design a five-storey building that can survive an earthquake.
2. Build a scale model of your design to test on a shake-table earthquake simulator.
3. Analyse the suitability of bamboo as a primary construction material.
4. Present your model and analysis of bamboo to the class.

Model requirements

- Total weight: no more than 1.5 kg
- Base area: no bigger than 20 cm × 20 cm
- Height: at least 50 cm tall
- Construction rules: no glue, staples, nails or pins. You must use interlocking pieces (e.g. LEGO, straws or other materials).
- Freestanding: it cannot be stuck to the table in any way.

Bamboo analysis

Analyse the idea of using bamboo as a primary construction material in earthquake-prone areas. This involves:

- researching the properties of bamboo, such as flexibility, strength and availability
- identifying evidence needed to support bamboo as a suitable material for earthquake-resistant buildings
- considering practical limitations, such as cost, cultural acceptance and environmental impact
- justifying your conclusion about whether bamboo could work as a solution for all buildings in earthquake areas.

Presentation

Before testing your model on the shake table, you will need to do the following.

- Explain your design: describe the main features of your building and why it is earthquake-proof.
- Connect to real-life engineering: explain how your model would work in real life to protect against earthquakes.
- Discuss your analysis of bamboo: present your conclusions on using bamboo for earthquake-resistant construction, based on the evidence you researched.

Tips for success

- Research earthquake-proof designs: look at how real engineers use techniques such as flexible materials, shock absorbers and strong foundations.
- Investigate bamboo properties: explore case studies or examples of bamboo buildings in earthquake-prone areas.
- Think critically: consider both the strengths and challenges of using bamboo and identify the evidence you would need to justify it.

Scientific methods, conclusions and claims can be analysed to identify assumptions, possible sources of error, conflicting evidence and unanswered questions (VC2S8I06)

6.6 Activities

learnon

6.6 Quick quiz on	6.6 Exercise

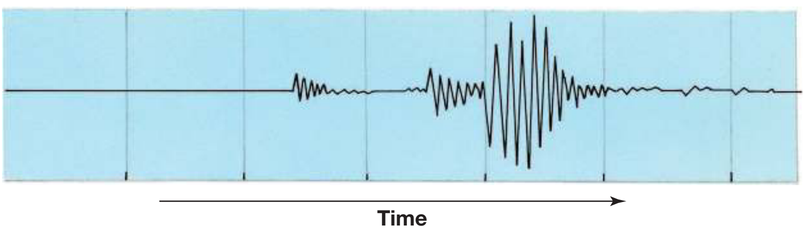
LEVEL 1	LEVEL 2	LEVEL 3
1, 3, 4, 7	2, 5, 6, 8	9, 10, 11

Remember and understand

1. MC What causes earthquakes?
   A. Strong winds moving across Earth's surface
   B. Sudden movements of tectonic plates along fault lines
   C. Changes in ocean currents beneath the sea floor
   D. Volcanic eruptions pushing magma into the atmosphere
2. **Distinguish** between an Earth tremor and an earthquake.
3. **Name** the point at which an earthquake begins.
4. **State** where the epicentre of an earthquake is relative to the focus.

Apply and analyse

5. **Explain** what the Richter scale measures.
6. SI A seismograph record is shown. Use this image to complete the following.
   a. **Identify** and label the P- and S-waves.
   b. **Identify** and label the surface waves.
   c. **Describe** how the record would look if the seismograph was further away from the epicentre.



7. **Explain** how seismologists are able to make predictions about the likelihood of an earthquake.
8. **Explain** why a tsunami only a few metres high in open ocean can reach heights of up to 30 m by the time it reaches land.

9. **SI** The table lists the number of deaths resulting from some of the major earthquakes over the last 40 years.

Year	Location	Number of deaths (approx.)	Richter scale magnitude
1994	Los Angeles, USA	57	6.6
1995	Kobe, Japan	6400	8.2
1999	Iznit, Turkey	17 000	8.4
2001	Gujarat, India	20 000	8.9
2003	Bam, Iran	26 000	6.6
2004	Sumatra, Indonesia	230 000	9.0
2008	East Sichuan, China	90 000	8.9
2010	Haiti (Caribbean Sea)	316 000	8.0
2011	Sendai, Japan	21 000	9.0
2015	Nepal	8964	8.8
2021	Haiti	2250	8.2
2023	Turkey and Syria	50 000	7.8

a. **List** two earthquakes that provide evidence that the Richter scale does not indicate the loss of life in earthquakes.
b. **Explain** what factors, apart from the magnitude, affect the number of deaths in an earthquake.
c. **Identify** how much more energy was released by the 2004 Sumatra earthquake than the 2010 Haiti earthquake.
d. **Suggest** why there may have been more fatalities during the Haiti earthquake.

Evaluate and create

10. **SI** You are requested to measure the magnitude and location of an earthquake. **Explain** how you would go about each.
11. **Explain** why Indonesia is more likely to experience major earthquakes compared to Australia.

Answers and sample responses are available in your digital formats.

LESSON 6.7 Volcanoes

LEARNING INTENTION

In this lesson you will understand how volcanoes form, where they occur, their impacts and the insights provided by Aboriginal and Torres Strait Islander Peoples' knowledge.

6.7.1 Mountains of fire

While most changes in Earth's crust happen slowly and go unnoticed, volcanic eruptions show that some changes can be dramatic.

Volcanoes form when molten rock from beneath Earth's surface pushes through a weakness in the crust. When a volcano erupts, it releases **lava**, ash and gas. Many people imagine volcanic eruptions as violent explosions with towering ash clouds, but eruptions can vary greatly — some are explosive, while others are much calmer.

Scientists who study volcanoes are called volcanologists.

KEY IDEA

The word 'volcano' comes from the name of the ancient Roman god, Vulcan, who was the god of fire.

What comes out of a volcano?

Deep beneath a volcano is a **magma** chamber where molten rock is stored. When pressure builds up, steam is often the first thing to escape through the volcano's vents. During an eruption, lava flows out, along with pressurised red-hot rock fragments, dust, ash, steam and other gases.

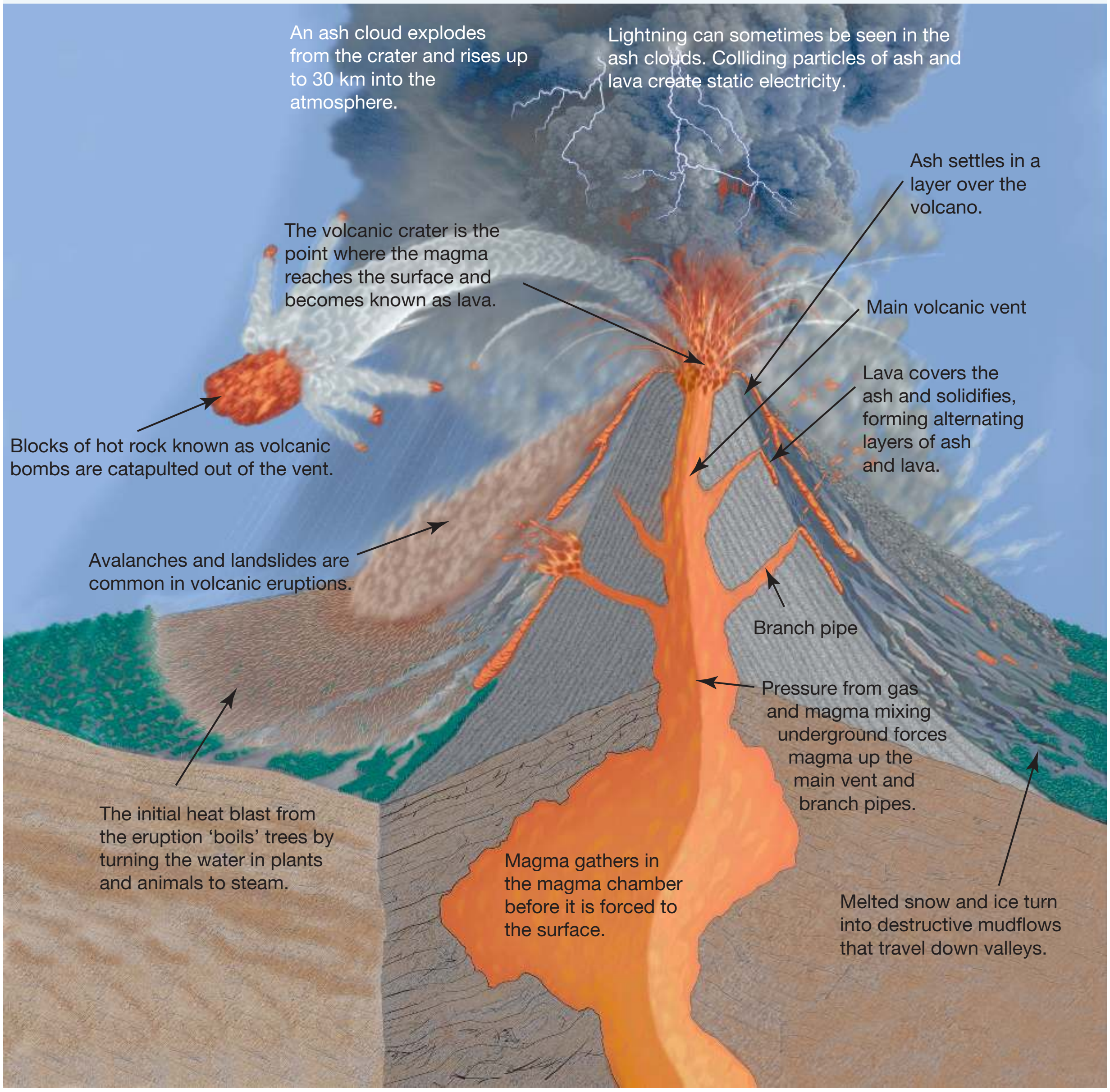
How runny or sticky that lava is will help to control how explosive the eruption is as well as the shape of the volcano. Larger rock fragments blown out of the crater are called **volcanic bombs** (see figure 6.39). The gases released include carbon monoxide and hydrogen sulphide, which smells like rotten eggs.

TABLE 6.5 Types of lava flows

Runny lava	Sticky lava
Gas escapes easily, leading to calmer eruptions or small lava fountains.	Gas is trapped, keeping the lava pressurised, leading to a highly explosive eruption as the gas rapidly expands at the surface.
Spreads over large areas, cooling to form volcanic plains (e.g. Victoria's western district, Melbourne).	Lava does not travel far, building steep cone-like mountains.

FIGURE 6.39 Volcanic bombs in Teide National Park, Spain

FIGURE 6.40 Parts of an erupting steep volcano formed with sticky lava



CASE STUDY: Forming a volcano

On a cool winter's day in 1943, a small crack opened in a field of corn on a quiet, peaceful Mexican farm. When red-hot cinders shot out of the crack, the shocked farmer tried to fill it with dirt. The next day, the crack had opened into a hole over 2 m in diameter. A week later, the dust, ash and rocks erupting from the hole had formed a cone-shaped mound 150 m high! Explosions roared through the peaceful countryside and molten lava began spewing from the crater, destroying the village of Paricutin. The eruptions continued and, when the eruptions stopped in 1952, the new mountain named Paricutin was 410 m high.

This volcano of Paricutin is one of several volcanoes that string down the western side of Mexico. Why are they there? They are a part of the Ring of Fire that circles the Pacific Ocean, and are formed from the subduction of oceanic crust under continental crust.

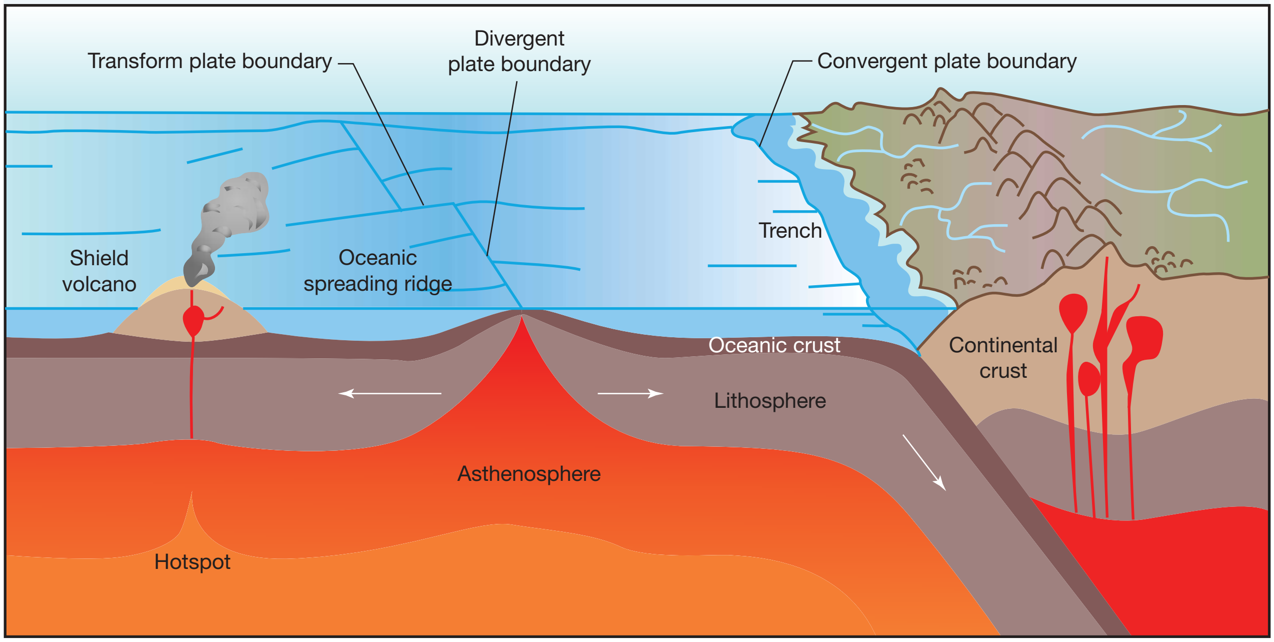
FIGURE 6.41 The volcano of Paricutin formed in just nine years.

6.7.2 Where do volcanoes occur?

Most volcanic activity on Earth occurs along two types of plate boundaries: mid-ocean ridges and subduction zones. At mid-ocean ridges, basalt lava erupts to produce new oceanic crust. At subduction zones, volcanoes are created on the overriding plate as melt from the subducting plate rises up through the mantle and crust.

A third setting for volcanoes is within plates.

FIGURE 6.42 Volcanism resulting from two different plate boundaries: convergent and divergent plate boundaries. Can you identify a volcano in the diagram that is not related to a tectonic plate boundary?



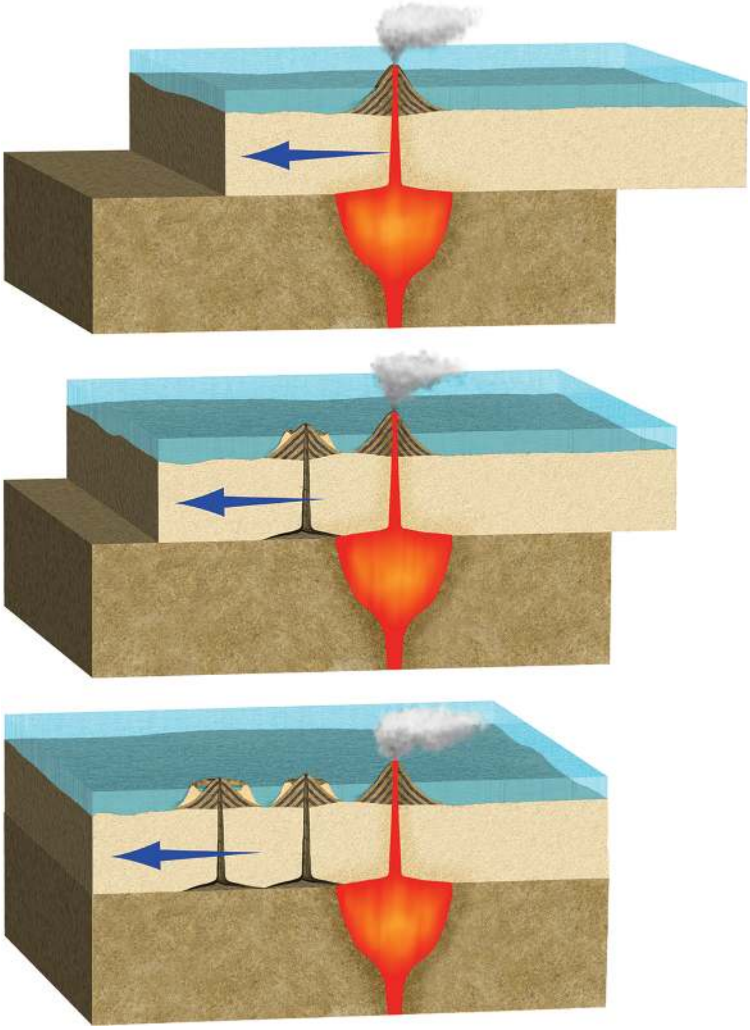
Hotspots

The Hawaiian Islands are volcanic, but they do not align with any tectonic plate boundaries. While most volcanoes form at the edges of Earth's crustal plates, some are found over **hotspots**. A hotspot is an area in the crust where extremely hot mantle rock rises and pushes magma upward.

Hotspots can create chains of volcanoes that get older the farther they are from the active hotspot. This suggests that the hotspot stays in the same place while the crust moves over it. For example, the Hawaiian Islands are thought to have formed as the Pacific Plate moved over a stationary hotspot.

Not all scientists agree on the hotspot theory. Some believe hotspots may lie closer to the surface and move slowly over time, while others question whether hotspots exist at all. This uncertainty is part of science, and why scientists continue to study and explore Earth's processes!

FIGURE 6.43 The formation of a hotspot volcanic chain in the ocean, where the oldest volcanic feature is the furthest away from the hotspot. As the older volcanoes become further away from the source of magma and heat, they erode and sink below the ocean.



Underwater volcanoes

Volcanoes do not just erupt on land — many are active below the ocean. Ocean ridges are long, continuous belts of underwater volcanoes with **black smokers**. These are vents on the sea floor that release superheated water full of dissolved elements from the ocean crust. Some scientists think that life on Earth might have begun around black smokers.

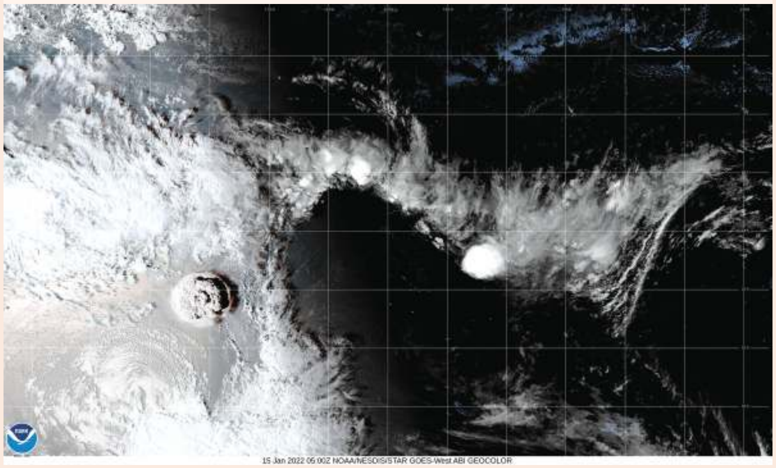
Underwater volcanoes are usually hidden from view. However, if enough lava builds up, it can rise above the ocean surface and form a volcanic island. Lord Howe Island, off the coast of New South Wales, formed this way about 6.5 million years ago.

CASE STUDY: A violent submarine eruption in Tonga

On 15 January 2022, a powerful explosive eruption from an underwater volcano in Tonga threw volcanic ash and gas high into the stratosphere, and sent atmospheric shockwaves and tsunami waves around the world. Hot magma full of volcanic gas was blasted out of the sea floor, rapidly hitting cold ocean water and causing an explosive eruption.

Thick ash blanketed the nearby islands, and tsunami waves severely damaged coastal communities and undersea communications cables. Tonga airports were shut down for several days due to ashfall. The umbrella cloud of ash reached 500 km in diameter and could be seen by satellite and the International Space Station! The volcano is part of a chain of volcanic islands that forms part of the Pacific Ring of Fire.

FIGURE 6.44 Underwater volcano eruption, Tonga, 2022



6.7.3 Active, dormant and extinct volcanoes

Active volcanoes are erupting or have erupted recently. An example is Mount Pinatubo in the Philippines, which last erupted in June 1991. This eruption killed 300 people and released so much smoke and ash that Earth's weather was cooler for over a year.

Dormant volcanoes have erupted in the last 10 000 years but are not currently active; however, they are considered likely to erupt again. Dormant means 'asleep', and these volcanoes could 'wake up' at any time. Mount Pinatubo was dormant before its 1991 eruption. **Extinct volcanoes** have not erupted for at least 10 000 years and are not expected to erupt again.

DISCUSSION

As a class, or in small groups, list some physical observations you could make about the appearance of a volcano that may help you to label it as active, dormant or extinct.

Volcanoes across eastern and southern Australia

Australia has many extinct volcanoes scattered across its eastern and southeastern landscapes. The Glasshouse Mountains in Queensland were formed when lava cooled inside volcanic vents about 26 to 27 million years ago. In Victoria, smaller volcanoes such as Mount Buninyong near Ballarat and Tower Hill near Warrnambool were created much later, between 3 million and 30 000 years ago.

Mount Gambier in South Australia is a bit different. It might still be dormant instead of extinct because its last eruption could have happened as recently as 5000 years ago, or as far back as 28 000 years ago. After the eruption, the craters collapsed and filled with water, forming clear lakes. Some scientists believe it erupted about 6000 years ago, which suggests it might still be classified as dormant.

FIGURE 6.45 A small crater on the extinct Tower Hill volcano in Victoria

KEY IDEA

Australia is located near the centre of the Indo-Australian Plate, making it very geologically stable. As a result, it has very few recent volcanic eruptions and only experiences a small number of large earthquakes. However, the existence of ancient volcanoes suggests that Australia's tectonic history was much more active in the past.

CASE STUDY: Aboriginal and Torres Strait Islander Peoples and geological knowledge

Aboriginal and Torres Strait Islander Peoples have witnessed and recorded volcanic activity and other geological events for thousands of years. Researching the cultural accounts of Aboriginal and Torres Strait Islander Peoples provides valuable evidence of events such as earthquakes, volcanic eruptions and tsunamis that have shaped Australia's landscape.

For example, the Boandik Peoples of south-eastern South Australia have oral stories suggesting their ancestors saw volcanic eruptions near Mount Gambier, which last erupted around 5000 years ago. Today, four volcanic craters remain in the area.

Cultural knowledge spanning thousands of years

For over 60 000 years, Aboriginal and Torres Strait Islander Peoples have observed and remembered geological changes and extreme weather events. Their knowledge has been passed down through story, song, dance and art, encoding important details that allow this information to remain intact for thousands of years.

To preserve this knowledge, only specific custodians — men or women, depending on the knowledge — are chosen to learn and pass it on when ready.

Examples of geological knowledge in cultural accounts

- The Awabakal Peoples of New South Wales share knowledge of earthquakes.
- The Gundungarra Peoples of south-eastern New South Wales and the Kambure Peoples of Western Australia have accounts of tsunamis.

- The Ngadjon-Jii Peoples in Queensland describe volcanic activity from 17 000 years ago, explaining the formation of volcanic crater lakes and the changes caused by eruptions.
- The Bungandidj People of Victoria have oral records spanning at least 4000 years, describing the volcanic events that formed the crater lakes at Budj Bim National Park.

Why research cultural accounts?

The knowledge held by Aboriginal and Torres Strait Islander Peoples predates European investigations and offers unique insights into Australia's geological past. Recent scientific research has confirmed the accuracy and significance of this knowledge, highlighting its importance in understanding historical geological events.

FIGURE 6.46 Hand stencil art at Carnarvon Gorge, Queensland

6.7.4 The impact of volcanoes on Earth

Volcanoes have a big impact on Earth's climate and life. Scientists think they may have created the warm ocean environments where life first started. They also released gases that formed our atmosphere and still play a role in climate change by adding or removing carbon dioxide.

Deep under the ocean, volcanic vents called black smokers release water that is over 300 °C. When the hot water meets cold ocean water, it looks like 'smoke'. These vents create habitats for unique animals such as giant tube worms, crabs and fish that survive in extreme heat and sulfur-rich water.

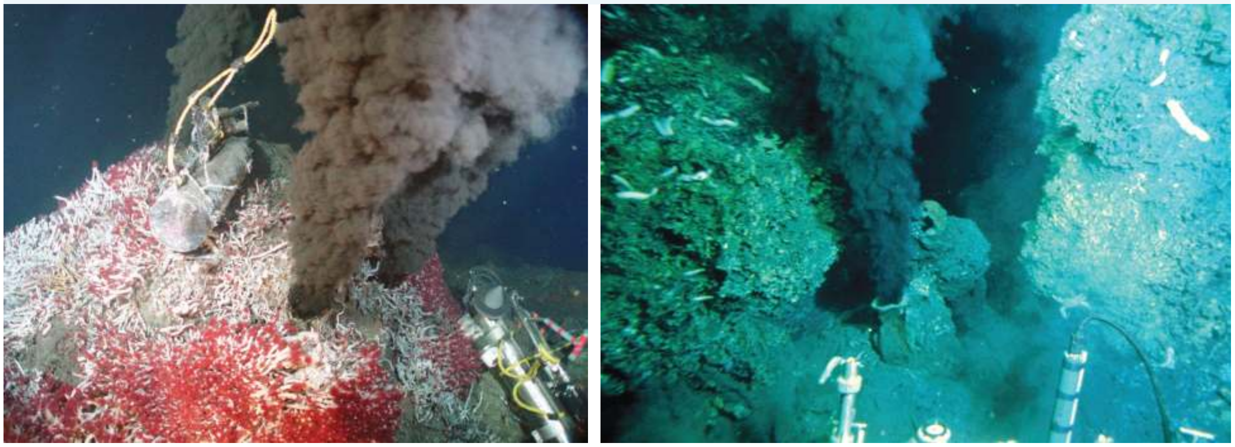
Volcanic rocks are important because they contain minerals that help us build modern technology and provide nutrients that plants and animals need. But volcanic eruptions can also cause problems:

- They can destroy farmland, leading to famine.
- Poisoned water supplies can cause droughts.
- Ash and gases can pollute the air, harming people's health.

Volcanoes have even wiped out entire cities, such as Pompeii in Italy, which was buried by the eruption of Mount Vesuvius in 79 AD.

Volcanoes are also linked to mass extinctions. About 252 million years ago, huge eruptions during the Late Permian extinction covered an area as large as Western Europe in lava. This lava released toxic gases that changed the atmosphere, causing the most severe extinction in Earth's history. Many species on land and in the oceans were wiped out.

FIGURE 6.47 Black-smoker volcanic vents in the Pacific Ocean



ACTIVITY: Ancient or recent geologic event

Create a video about an ancient or recent geologic event that demonstrates how dynamic the geosphere is. It can be like a documentary or news report. Be sure to select appropriate language, models or analogies to engage a specific audience.

6.7 Activities

learnon

6.7 Quick quiz on	6.7 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 4	5, 7, 8, 9	6, 10, 11

Remember and understand

1. MC What can cause a volcano to erupt?
   A. Strong winds carving deep valleys into mountains
   B. Sudden shifts in Earth's magnetic field
   C. Pressure from molten rock (magma) rising through the crust
   D. Large ocean waves crashing into coastal cliffs
2. **List** the substances that emerge from a volcanic crater during an eruption.
3. MC What is the difference between a dormant volcano and an extinct volcano?
   A. Dormant volcanoes have never erupted, while extinct volcanoes erupt frequently.
   B. Dormant volcanoes may erupt again in the future, while extinct volcanoes are unlikely to ever erupt again.
   C. Dormant volcanoes are found underwater, while extinct volcanoes are only found on land.
   D. Dormant volcanoes are smaller than extinct volcanoes.
4. **Describe** what a hotspot is.

Apply and analyse

5. **Explain** in terms of the plates that form Earth's crust why Australia experiences little volcanic or earthquake activity.
6. Use a Venn diagram to show the differences and similarities between magma and lava.
7. How do you know that many of the volcanoes in the western district of Victoria had runny lava? **Explain** your answer.
8. **Explain** how a volcano can affect Earth's weather.

9. A photograph of the crater at Mount Gambier is shown. Should Mount Gambier be described as an extinct or dormant volcano? **Explain** your answer.

10. **Explain** how the islands of Hawaii were formed.

Evaluate and create

11. SI A volcanologist working for the government is assigned to assess the probability of a volcanic eruption from a local volcanic feature. The volcanologist decides to first map the rocks around the volcano and obtain the ages of these rocks to piece together the eruption history.
    a. **Explain** why it is important for the geologist to map the rocks and obtain their ages.
    b. **Suggest** one additional investigation that may improve the final conclusion.

Answers and sample responses are available in your digital formats.

LESSON 6.8 Human response to tectonic events

LEARNING INTENTION

In this lesson you will understand the impacts of tectonic events on humans, and engineering solutions to mitigate them.

6.8.1 Tectonic forces and natural disasters

Tectonic forces create natural hazards such as volcanoes, earthquakes, tsunamis and avalanches. When these hazards cause major loss of life, property damage or harm to the economy, they are called natural disasters.

For example, on 28 June 2024, a 7.2 magnitude earthquake struck off the coast of Peru, causing significant destruction. The earthquake killed at least 30 people, affected over 100 000 people and damaged or destroyed more than 20 000 buildings.

To reduce the impact of these events, scientists and engineers work together:
- Geologists study, monitor and predict geological processes.
- Engineers design data-collection devices, rescue equipment and structures such as earthquake-resistant buildings, bridges and channels to redirect lava flows. They also raise buildings on stilts to reduce damage from flooding.

SCIENCE AS A HUMAN ENDEAVOUR: An early Chinese earthquake detector

In the year 132 AD, a Chinese scholar by the name of Zhang Heng invented the first seismoscope to measure earthquakes. Long before the theory of plate tectonics, he believed that observations of the direction, force and timing of winds could indicate and predict events on Earth and in space.

A seismoscope records the motions of Earth's shaking, but unlike a seismometer, it does not retain a time record of those motions. To indicate the direction of a distant earthquake, Zhang's device dropped a bronze ball from one of eight tubed projections shaped as dragon heads. The ball fell into the mouth of one in a circle of metal toads, each representing a compass direction.

One day Zhang's device was triggered but no seismic disturbance was felt. Several days later a messenger arrived from the west and reported that an earthquake had occurred 500 km away in the direction that Zhang's device had indicated!

FIGURE 6.48 An antique Chinese seismoscope

1. How did Zhang Heng's seismoscope work to detect the direction in which an earthquake occurred?
2. Why was Zhang's device considered groundbreaking, even though it did not provide a time record of Earth's movements?
3. How did Zhang Heng's invention demonstrate the importance of observing and understanding natural phenomena to predict and explain events?
4. Why was it significant that Zhang's seismoscope accurately indicated an earthquake 500 km away? How could this knowledge have been useful to the people of that time?
5. What advancements in earthquake detection technology have been made since Zhang's invention? How do modern seismometers improve upon his ideas?
6. Why is it important to communicate data about earthquakes effectively in modern society? How might this information influence community safety policies?
7. What are some ethical considerations when using earthquake detection technologies to inform the public about seismic risks?
8. How can earthquake detection systems benefit communities in earthquake-prone regions today, and what challenges remain in ensuring their effectiveness?

Communication of scientific knowledge has a role in informing individual viewpoints, and community policies and regulations (VC2S8H04)

6.8.2 Monitoring and predicting geohazards

The best way to reduce the impact of tectonic events, such as earthquakes and volcanic eruptions, is through preparation. This involves monitoring and predicting where and when these events might happen. Geological maps and geophysical images show the locations of faults and volcanoes where hazards are more likely.

Governments play a key role in disaster planning. This often includes:
- education and training
- emergency communication and evacuation plans
- health services (both physical and mental)
- restoring power, transport and telecommunications
- rebuilding damaged communities.

Historical records are some of the best tools for predicting geohazards. These include written documents and the oral knowledge of Aboriginal and Torres Strait Islander Peoples, which often describes geological events. If a disaster occurred hundreds or thousands of years ago, it is likely to happen again.

Technology

Modern technology helps us track tectonic activity and predict potential disasters. Scientists and engineers constantly work to improve tools and develop new ideas.

TABLE 6.6 Technology that tracks and predicts natural disasters

Technological device	Role in tracking and predicting natural disasters
Satellite	Radar images show changes in volcanoes, ash clouds, fault lines and areas prone to landslides. Satellites can also detect heat changes, signalling possible eruptions.
Global Positioning System (GPS)	Tracks ground movement near faults, volcanoes and landslides using data from satellites orbiting 20 000 km above Earth.
Seismometer	Detects the location and size of seismic activity, which can warn of earthquakes or volcanic eruptions.
Tiltmeter and **Strainmeter**	Measure tiny changes in ground slope and shape that may signal an eruption.
Gas and Water Sensor	Detects increased gas output, new vents, changes in gas chemistry or rising temperatures, all of which can indicate volcanic activity.

Computer software

Computer models simulate disaster scenarios to test emergency plans and identify potential problems. For example, after the 2011 Fukushima nuclear reactor meltdown caused by an earthquake and tsunami, scientists used computer models to predict how **radioactive** material would spread and what health impacts it might have.

FIGURE 6.49 A small seismometer, about 20 cm across

DISCUSSION

Governing a society involves balancing public safety with maintaining economic stability. Mass panics can lead to economic collapse, raising the question: Should scientists always communicate all potential threats, or should they consider the risk of creating unnecessary fear?

Have a look at what happened ahead of the deadly earthquake in L'Aquila, Italy, in 2009.

6.8.3 Engineering solutions

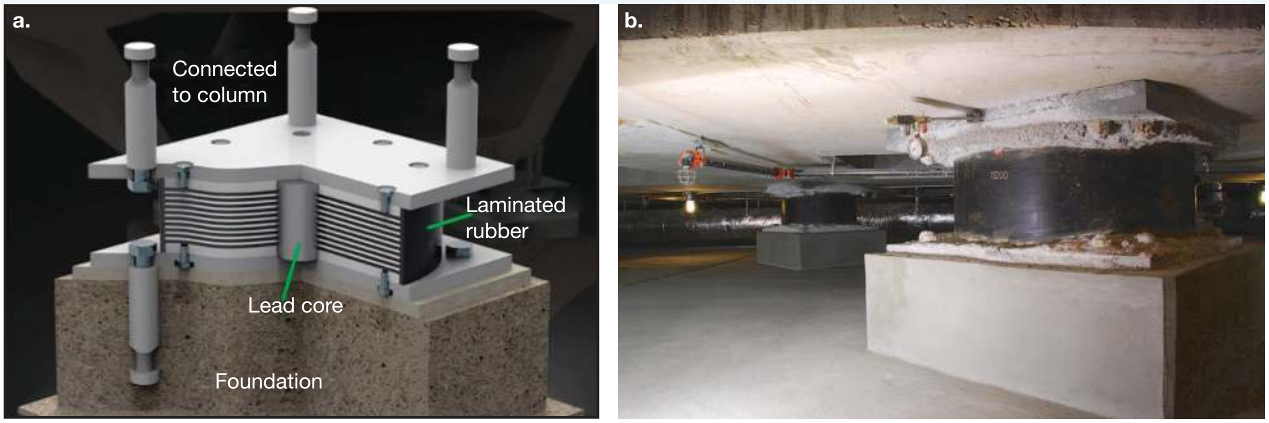
Earthquakes

The violent shaking and fracturing of the ground that accompanies an earthquake causes a great deal of damage to buildings and can destroy cities, with falling debris leading to much loss of life and injury. **Liquefaction** can make the ground soft and unstable, destroying roads, pipes and cables, and causing buildings to sink. Damage to services and loss of housing has a huge impact on the population and local economy, which can last for years.

New Zealand is a country with a long history of earthquakes and has been developing and improving building codes to deal with this over many years. The University of Canterbury has done research on how concrete behaves during earthquakes and has contributed to building design codes used around the world. Many buildings and bridges are protected with lead dampers and lead-and-rubber bearings invented in New Zealand. These devices in building foundations can reduce the motion caused by ground shaking. Flexible joints or ductile pipes are used for water pipelines across unstable ground to prevent rupture. Similarly, gas pipelines have been welded to prevent breakage or replaced by polythene pipes.

FIGURE 6.50 Damage from a magnitude 6.3 earthquake that hit Christchurch, New Zealand, on 22 February 2011

FIGURE 6.51 Earthquake solutions: **a.** A lead-and-rubber bearing **b.** A damper under a building



CASE STUDY: A dam designed to shake

The Clyde Dam in New Zealand is designed to withstand intense shaking. It is built across a fault and has been constructed with a specially designed slip joint. If the land on either side of the fault moves during an earthquake, the joint will allow sections of the dam to shift up to 2 m horizontally and 1 m vertically without the dam failing.

FIGURE 6.52 The Clyde Dam in New Zealand is designed to sustain earthquakes

SCIENCE AS A HUMAN ENDEAVOUR: Bamboo houses

In 2018, an earthquake reduced much of the island of Lombok in Indonesia to rubble, and killed 560 people. A visiting engineer noticed that bamboo houses withstood the shaking better than concrete ones. This is because bamboo houses move during earthquakes, allowing the energy to be dispersed. Bamboo is lightweight, strong, cheap and readily available in many earthquake-prone developing areas of the world, so is an ideal and sustainable building material. Engineers and University College London have since been working closely with the people of Lombok to design strong and safe bamboo houses.

FIGURE 6.53 A bamboo house

1. Why do bamboo houses withstand earthquakes better than concrete ones?
2. What properties of bamboo make it an ideal building material for earthquake-prone areas?
3. What are the environmental benefits of using bamboo as a building material compared to concrete?
4. How does the use of bamboo houses address economic and social challenges in developing countries such as Indonesia?
5. Why is it important for engineers to collaborate with local communities when designing bamboo houses?
6. What ethical considerations should be considered when promoting bamboo houses as a solution in earthquake-prone areas?
7. How could the knowledge gained from using bamboo houses in Lombok be applied to other earthquake-prone regions around the world?
8. What other natural or sustainable materials could be explored for building in areas with extreme environmental conditions?

Proposed scientific responses to socio-scientific issues impact on society and may involve ethical, environmental, social and economic considerations (VC2S8H03)

Volcanoes

Volcanoes can cause serious harm to people and the environment. They can destroy towns, natural resources and habitats, and lives are often lost. For example, in 79 AD, the Roman city of Pompeii was completely destroyed by the eruption of Mount Vesuvius.

Unlike earthquakes, volcanoes often show warning signs before they erupt. Geologists study the history and types of volcanoes, map volcanic deposits and use instruments to predict when and where an eruption might happen. Pyroclastic eruptions are faster and much more explosive than lava flows, making them particularly dangerous.

FIGURE 6.54 Mount Vesuvius and the remains of Pompeii

To help predict eruptions, engineers build devices that detect small changes in volcanoes, such as gas emissions, changes in shape and earthquakes near the volcano. In volcanic areas, especially in low-income regions, well-designed buildings can save lives and prevent injuries.

Volcanic ash, while similar to snowfall, is heavier, corrosive and potentially toxic. It can also be carried far distances with strong winds, making it a serious hazard. Buildings in volcanic areas should:

- have smooth, steep roofs to let ash slide off, with strong support and bracing for wind
- include windows and doors that can seal completely to keep out toxic gases
- be equipped with emergency supplies, such as gas masks and oxygen.

Proper planning and building design are crucial to reduce the risks from volcanic eruptions.

Tsunamis

Tsunamis can be caused by earthquakes or volcanic eruptions and are very destructive. The fast-moving water and waves can carry debris, sometimes on fire, which crashes into buildings and other structures. Tsunamis also cause erosion, washing away land, and strong winds can add to the damage.

FIGURE 6.55 Damage at Banda Aceh, Indonesia, after an earthquake and tsunami in December 2005

If you live in an area where tsunamis could happen, there are ways to make houses safer, including:

- using strong materials, such as reinforced concrete instead of wood, and building houses with deep foundations and adding escape routes, such as stairs or platforms, so people can climb to safety above the water
- raising buildings on stilts or platforms so they are above the wave level
- planting natural barriers such as trees or mangroves, or building slopes and ditches between the coast and the house to slow down the waves
- directing the waves by using angled walls or ditches to guide water away from homes
- building seawalls or embankments to block waves; but be careful — these can sometimes make waves taller or redirect them to other areas.

FIGURE 6.56 A tsunami evacuation structure at a beach in Japan. The platform is 12.5 m above sea level.

6.8 Activities

learnon

6.8 Quick quiz on	6.8 Exercise

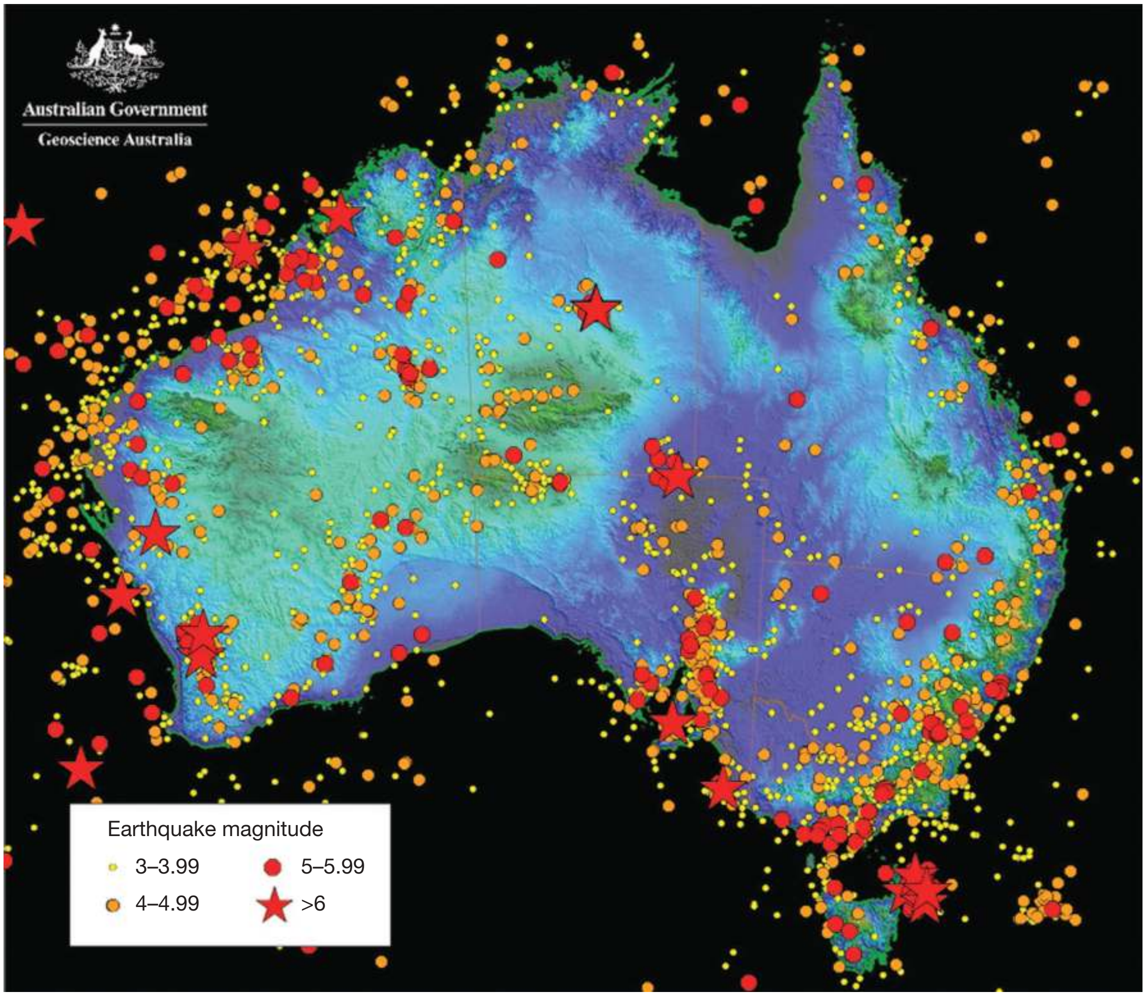
LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 8	3, 4, 6, 9	5, 7, 10

Remember and understand

1. MC What is the difference between a natural hazard and a natural disaster?
   A. A natural hazard causes damage, while a natural disaster only affects the environment.
   B. A natural hazard is a potential threat, while a natural disaster occurs when that threat causes destruction.
   C. Natural hazards only happen in remote areas, while natural disasters occur in cities.
   D. Natural disasters are caused by human activity, while natural hazards happen naturally.
2. **Describe** some hazards related to tectonic events.
3. **Name** the devices used to monitor tectonic activity.

Apply and analyse

4. **Explain** how Aboriginal and Torres Strait Islander Peoples pass on knowledge about geological events.
5. How do engineers help society deal with natural hazards? **Explain** with some examples.
6. The following image shows the locations of earthquakes that occurred in Australia between the years 1800 and 2000. Based on this, **name** two capital cities that are likely to have the greatest risk of earthquakes in the future.



7. In some areas, bamboo houses have been found to withstand earthquakes better than concrete buildings. **Explain** some other advantages of bamboo houses.

Evaluate and create

8. A geologist mapping a volcano in Queensland finds Aboriginal and Torres Strait Islander Peoples' art on the rocks near the summit. What could they do, apart from making geological observations, to find out more about the volcanic history? **Explain** your answer.
9. You have a forested block of land, 200 m^2, that extends from the beach to a low ridge at 10 m above sea level. Locate and **describe** the design of a simple house to best withstand a tsunami.
10. **Name** the type of app that might be useful during and following a natural disaster.

Answers and sample responses are available in your digital formats.

LESSON 6.9 Review

6.9 Success criteria

Tick the column to indicate that you have completed the lesson and how well you think you have understood it using the traffic light system.

(**Green:** I understand; **Yellow:** I can do it with help; **Red:** I do not understand)

Lesson	Success criteria	Green	Yellow	Red
6.2	I can describe Earth's internal layers.			
	I can discuss the theory of continental drift and the formation of the supercontinent Pangaea.			
6.3	I can discuss Marie Tharp's contribution to the theory of plate tectonics and the different forces involved in plate movement.			
6.4	I can describe the different types of plate boundaries and consider Australia's plate tectonic history.			
6.5	I can understand how tectonic forces from plate movements cause the crust to bend into folds or break into faults, shaping Earth's landscape and triggering earthquakes.			
6.6	I can explain how earthquake waves move.			
	I can outline methods used to measure earthquake waves.			
	I can evaluate their potential dangers.			
6.7	I understand how volcanoes form, where they occur, their impacts and the insights provided by the knowledge of Aboriginal and Torres Strait Islander Peoples.			
6.8	I understand the impacts of tectonic events on humans, and engineering solutions to mitigate them.			

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Post-test Topic 6 Post-test

eWorkbook Topic 6 eWorkbook

Digital document Key terms glossary

6.9 Activities

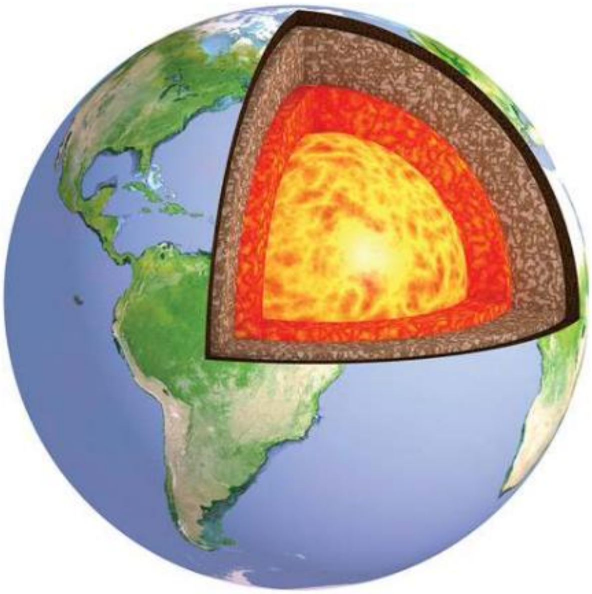
learnon

6.9 Review questions

■ LEVEL 1	■ LEVEL 2	■ LEVEL 3
1, 2, 4, 5, 9, 11, 13, 15	3, 6, 10, 12, 16, 18, 19	7, 8, 14, 17, 20, 21, 22

Remember and understand

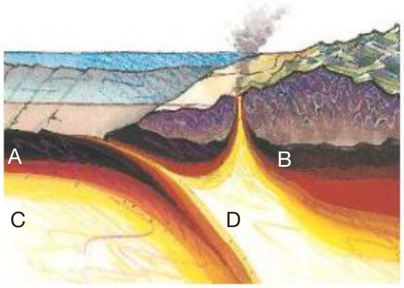
1. **Identify** the layers of Earth that have the following characteristics.
   a. Completely molten
   b. Solid but soft
   c. Solid and hard, and includes rock, soil and landforms
   d. Solid and mostly made of iron
   e. Lies above the surface
2. SI **Describe** two pieces of evidence that were used to develop Wegener's theory of continental drift.
3. **Explain** how scientists know about what lies deep below the surface of Earth without going there.



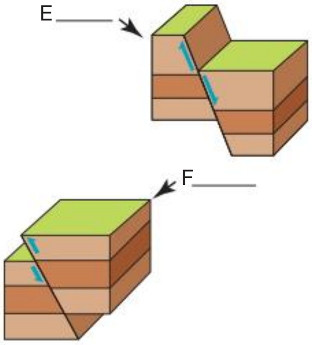
4. **Name** where you would find the youngest oceanic crust according to the theory of sea-floor spreading.
5. **Explain** how an ocean ridge is different from a subduction zone.
6. When oceanic crust pushes against continental crust, why does the oceanic crust slide underneath the continental crust? **Explain** your answer.
7. **Explain** the major difference between the continental drift theory and the theory of plate tectonics.
8. **Describe** the movements in Earth's crust that cause the folding of rock and have shaped many of Earth's mountain ranges.
9. **Explain** how faults are created.

10. **Examine** the following diagrams and label the features A–H using the following words: anticline, continental crust, magma, normal fault, oceanic crust, reverse fault, upper mantle, syncline.

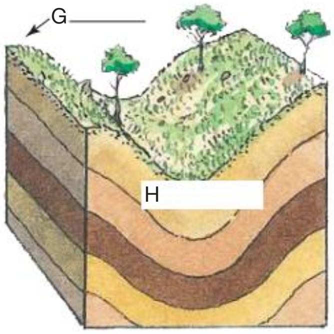
A subduction zone



Two types of faulting



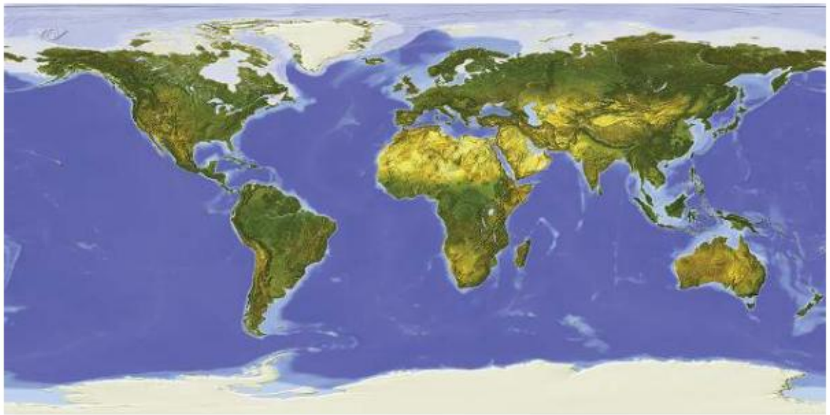
Folding upwards and downwards



11. **Distinguish** between the epicentre of an earthquake and its focus.
12. **Explain** what a seismograph is used to measure.
13. **Name** three gases that are released from a volcano.

Apply and analyse

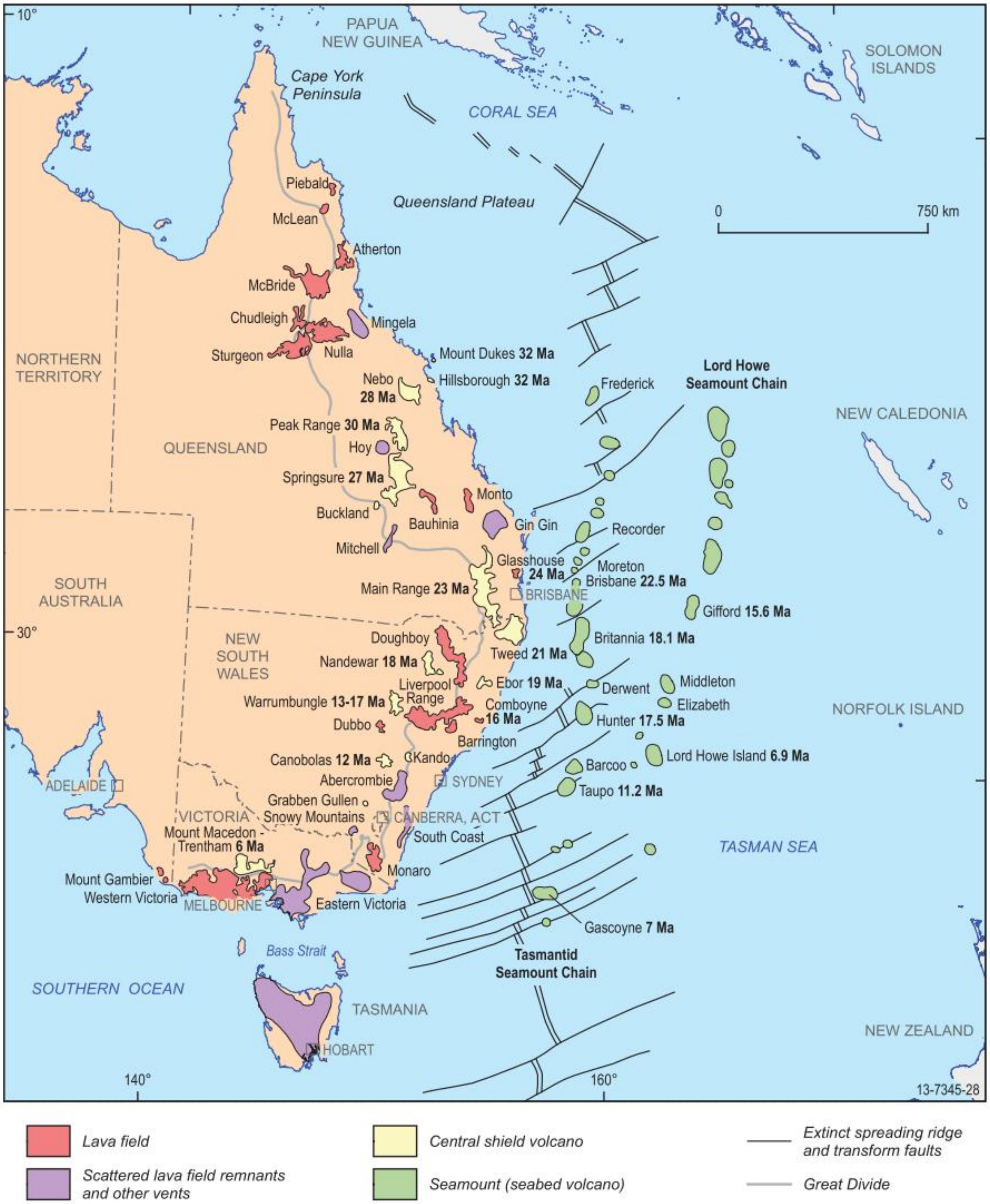
14. The San Andreas Fault runs along much of coastal California, including the cities of Los Angeles and San Francisco, and is susceptible to earthquakes.
    a. **Explain** why the San Andreas Fault is called a strike-slip fault.
    b. **Explain** what causes major earthquakes along this fault.
15. Using the image provided, **identify** where on Earth the Ring of Fire is and why it exists. **Explain** why it is called the Ring of Fire.



16. **Suggest** two reasons why an earthquake that registers 6.6 on the Richter scale can potentially cause more deaths and devastation than an earthquake that registers 8.9.
17. How much energy is released by an earthquake that registers 6.0 on the Richter scale relative to one that registers 8.0? **Explain** your answer.
18. **Explain** why Australia is less likely to experience volcanic activity and major earthquakes than New Zealand.
19. Tsunamis can form due to fault movements on the ocean floor, but there are other geologic events that can trigger a tsunami, such as a huge coastal or underwater landslip. How can a large landslip trigger a tsunami? **Explain** your answer.
20. Before an explosive volcano erupts, its vents are blocked with thick, sticky lava.
    a. What change takes place to cause the volcano to erupt?
    b. How would runny lava change the eruption style?

Evaluate and create

21. SI Observe in the following figure the age of the volcanic shield volcanoes along the Great Dividing Range. **Recall** that the eastern margin of Australia has not been located near a plate boundary for the last 50 million years.



a. What is the pattern to the age relative to direction?

b. Based on your knowledge and observations, how would you **explain** the origin of the volcanoes?

c. Are there any inconsistencies to that pattern or other reasons as to why you may question the conclusion?

22. According to the theory of plate tectonics, Earth's crust is divided into slowly moving plates.
   a. What makes the plates move?
   b. What can happen when two plates slide past each other?
   c. How does the theory of plate tectonics explain the growth of the Himalayas? Your answer should include reference to relevant plate boundaries, rock density and any limiting factors on the height of mountain chains.

Answers and sample responses are available in your digital formats.

To test your understanding and knowledge of this topic, go to your learnON title at www.jacplus.com.au and complete the **post-test**.

7 Rocks

CONTENT DESCRIPTION

Key processes of the rock cycle occur over different timescales; the properties of sedimentary, igneous and metamorphic rocks not only reflect their formation but also impact their usefulness and determine the methods used when mined (VC2S8U11)

Source: Victorian Curriculum F–10 Version 2.0

LESSON SEQUENCE

LESSON 7.1 Overview

7.1.1 Introduction

Did you know Earth's surface is always changing? While volcanoes and earthquakes can cause dramatic, sudden changes, most changes happen slowly over millions of years. Rocks on and beneath Earth's surface hold amazing clues about these changes, like pages in a history book just waiting to be read!

Geologists are scientists who study rocks to uncover these incredible stories. In Cerin, France, limestone rocks hold the fossil of an extinct reptile called Crocodilaemus robustus, which lived about 160 million years ago in a tropical lagoon. This fascinating creature was only 60 cm long, with long back legs that made it a great walker on land. Its strong plated armour protected its belly and tail but made it a slower swimmer. Imagine what it must have looked like roaming the lagoon! If you visit Cerin today, you won't find a tropical lagoon or a living Crocodilaemus robustus.

In November 2023, researchers exploring the underwater caves of South Australia's Limestone Coast found fossils of megafauna, including the remains of a short-faced kangaroo and marsupial lion (Thylacoleo carnifex). These animals lived between 50 000 and 100 000 years ago and entered these caves when water levels were much lower. The discovery gives clues about what the environment was like back then and why these megafauna disappeared.

Rocks do not just hold stories of the past — they are also incredibly useful. Rocks provide valuable materials such as metals, minerals and stone used to build homes, roads and even technology. Limestone, for example, is used to make cement, an important ingredient for modern construction.

Studying rocks helps to unlock these amazing stories from the past, determine their economic value and even gives hints about what might happen in the future.

FIGURE 7.1 Fossil of *Crocodilaemus robustus* that lived 160 million years ago

DISCUSSION

1. Which rock is light enough to float on water?
2. Which rocks are formed from the remains of living things?
3. What do butterflies, frogs, werewolves and metamorphic rocks have in common?
4. How do scientists know what long-extinct living things looked like, how they walked and what they ate?
5. How can whole skeletons of animals be fully preserved for millions of years?
6. What can you learn from a dinosaur footprint?
7. Why did the dinosaurs vanish from Earth 65 million years ago?

SCIENCE INQUIRY: Rock types

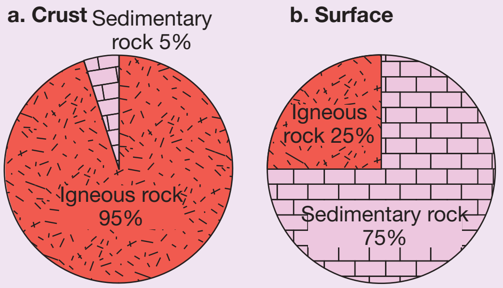
Rocks are classified as either igneous, sedimentary or metamorphic. Each of these names provides a clue to how they formed. For example, the word 'igneous' comes from the Latin word *ignis*, meaning 'fire'. That is, these rocks have formed from the cooling and hardening of fiery hot, melted rock. As a class, discuss the following questions.

1. The word 'sediment' comes from the Latin word *sedere*, meaning 'settle', or 'sit'. What could this imply about how sedimentary rocks form?
2. The word *meta* is Greek for 'change' and *morpho* means 'form'. What could this imply about how metamorphic rocks form?

Further to your answers above, consider figure 7.2, which illustrates the distribution of rocks in the crust (the top layer that averages 6–35 km thick) and the surface of Earth. In these pie charts, metamorphic rocks are included within the rocks that they were formed from. That is, metamorphic rocks derived from sedimentary rocks are included in the sedimentary rock total.

3. Igneous rocks, or metamorphic rocks derived from igneous rocks, account for 95 per cent of all rocks in Earth's crust; sedimentary rocks account for 5 per cent. However, when we look at just Earth's surface, sedimentary rocks make up 75 per cent. What does this tell you about the nature of igneous and sedimentary rocks?

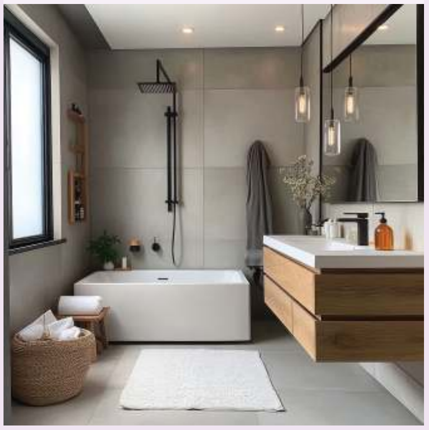
FIGURE 7.2 The distribution of rocks in the crust and across the surface of Earth



Bathroom rocks

When you last used the bathroom, you probably were not thinking about rocks. After all, what does a bathroom have to do with rocks? But where did the materials to make the shower recess come from? What about the taps and pipes that deliver the water? Where do the materials to make tiles come from? And what about the toothpaste? The answers to all of these questions lead back to rocks. For example, metals are extracted from rocks and are used to make the steel taps.

FIGURE 7.3 Taps, tiles, glass and even mirrors. Where do the materials needed to produce these come from?



Work in small groups to research and answer the following questions. You may wish to use the weblink 'Mining makes your Smart Home' in the resources tab.

4. What materials are mirrors made from?
5. What metal is primarily used to make bathroom taps? Where do we get the metal?
6. What are bathroom tiles and the toilet basin made from?
7. List some building materials that are:
   a. made directly from rocks
   b. not made directly from rocks but can be traced back to rocks.

Information and processed data can be analysed to show patterns, trends and relationships, and to identify anomalies (VC2S8I05)

learnon

Pre-test	Topic 7 Pre-test
eWorkbooks	Topic 7 eWorkbook Student learning matrix
Practical investigation eLogbook	Topic 7 Practical investigation eLogbook
Digital document	Key terms glossary

LESSON 7.2 Minerals

LEARNING INTENTION

In this lesson you will:
- define a mineral
- recognise that minerals have unique chemical and physical properties
- understand how minerals differ from rocks.

7.2.1 What is in a rock?

Firstly, what is a rock? To call something a rock, it needs to be a naturally occurring, coherent collection of **minerals**, organic material and/or glass.
- Naturally occurring: must be formed by natural process; it is not manufactured
- Coherent: holds together
- Collection of minerals, organic matter and/or glass: some rocks only contain a collection of one type of mineral, some contain several different minerals, some are entirely made of glass and some are composed of large volumes of organic matter (e.g. coal).

Never confuse rocks and minerals. Minerals are to rocks as letters are to words.

DISCUSSION

Discuss whether these items are considered to be a rock or not. Be sure you can explain your answer.
- footpath cement
- benchtop granite
- bricks
- marble chopping block
- garden soil

7.2.2 Minerals

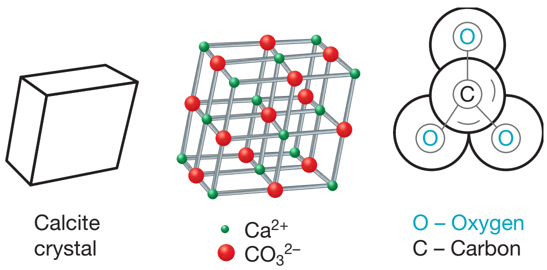
Most rocks are made up of substances called minerals. A mineral is any naturally occurring solid substance with a definite chemical composition and crystal structure.

Chemical composition

Elements found naturally in their uncombined, pure form are also minerals. These elements, called **native elements**, include diamonds (pure carbon) and gold.

Most minerals in rocks are **compounds**, in which one or more elements bond together. For example, the mineral calcite is the combination of one calcium (Ca), one carbon (C) and three oxygen (O) atoms to make calcium carbonate ($CaCO_3$) (figure 7.4). Calcite is the primary mineral found in the rocks limestone and marble.

FIGURE 7.4 The mineral calcite is chemically known as calcium carbonate.



The most common group of minerals is the **silicates**, in which elements bond to oxygen (O) and silicon (Si). This is because oxygen and silicon are the most abundant elements in Earth's crust. The mineral quartz (figure 7.5) is a simple silicate (SiO_2), whereas clay is a complex silicate ($Al_4Si_4O_{10}(OH)_8$).

FIGURE 7.5 Quartz is one of the most common minerals in Earth's crust.

Wherever you go, a specific type of mineral will have the same chemical composition. The colours and shapes may change a little, which tells us more about how they were formed and provides clues about the past.

Crystal structure

The elemental atoms that join to form minerals create regular geometric shapes called **crystals**. The crystal shape reflects the organisation of the atoms inside. The physical environment around them can also impact the crystal structure, where additional pressure or compaction will force the structure to be more closely packed (figure 7.6).

FIGURE 7.6 A close-up of granite, a rock made of many different types of minerals, shows how the mineral crystals grew into interlocking shapes.

The size of crystals depends on how fast they form and how much space is available. If a crystal forms quickly, do you think it would be smaller or bigger? The answer is smaller, because it had less time to grow.

The quartz crystals in figure 7.5 have had a lot of time and space to grow. Quartz, one of the most common minerals, consists of hexagonal crystals of silicon dioxide (SiO_2), which make it look like a six-sided column with a six-sided pyramid at both ends.

EXTENSION: Are diamonds forever?

Although graphite (which can be found in some of your pencils) and diamonds are both minerals with pure carbon as their chemical composition, they are physically very different. Graphite is soft enough to leave behind traces when rubbed on paper, and diamonds are the hardest minerals on Earth. In fact, diamonds are so hard that they are used to drill into rocks.

If they are made of the same element, why do they display such different properties? This is because they formed under different pressure conditions. To get the crystal structure of a natural diamond, carbon crystals have to form under pressures that are only reached at distances deeper than 150 km into Earth. This is one of the reasons they are so rare here on the surface. The bad news is that at the surface where the pressure is much less, diamonds are slowly changing back to graphite — very, very slowly.

FIGURE 7.7 Natural graphite form

FIGURE 7.8 Faceted diamond, created by grinding a diamond on a spinning lap

DISCUSSION

Is table salt a mineral? Think carefully about your answer and suggest reasons for and against classifying it as a mineral. How about ice that forms on car windows during a freezing winter night?

ACTIVITY: Grow your own crystals

Materials

- alum, Epsom salts or non-ionised table salt
- warm water
- a shallow bowl or small jar
- a spoon
- pipe cleaners (or string if unavailable)
- a pencil or chopstick

Instructions

1. Start by making a warm, saturated solution. Gradually stir alum, Epsom salts or table salt into warm water until no more can dissolve (you will see some crystals settle at the bottom).
2. Allow the solution to cool.
3. While waiting, twist your pipe cleaner into a fun shape, like a spiral or heart.
4. Place the cooled solution into your shallow bowl or small jar. Suspend your pipe cleaner into the solution by tying it to a pencil or chopstick resting on top of the bowl or jar. The pipe cleaner should hang in the liquid but not touch the bottom.
5. Set your container aside somewhere safe and observe over time. Depending on the material, crystals may start forming within a few hours or take up to a week.

Questions

- What shapes do you notice in your crystals?
- Are your crystals all the same size? How big are your largest and smallest ones?
- How long did it take for the first crystals to appear?

7.2.3 Identifying minerals

Although colour might seem to be the quickest way to identify a mineral, it is not reliable. Many different minerals have similar colours. Some samples of the same mineral can have different colours due to small impurities. For example, quartz can be colourless like glass, or may be pink, violet, brown, black, yellow, white or green. Therefore, a combination of physical properties must be used to identify minerals.

Additional mineral properties include the following:

- The **lustre** of a mineral describes the way that it reflects light. Minerals could be described as metallic or non-metallic. Non-metallic characteristics include dull, pearly, waxy, silky or glassy.
- The **streak** is the colour of a powdery mark left by a mineral when it is scraped across a hard surface, such as an unglazed white ceramic tile. It is a more reliable property to distinguish between two minerals than colour is.
- The **hardness** of a mineral can be determined by trying to scratch one mineral with another. The harder mineral leaves a scratch on the softer mineral.

FIGURE 7.9 Streaks from minerals with a metallic lustre (left) and an earthy, dull lustre (right)

KEY IDEA

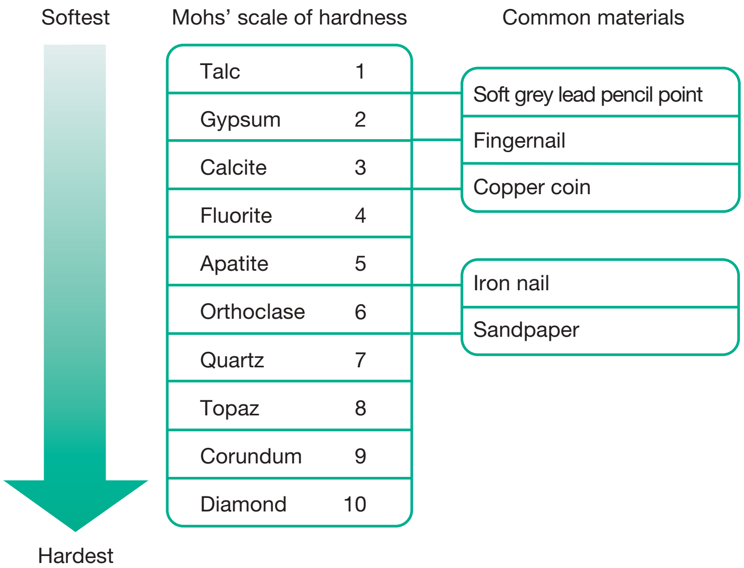
Minerals generally have no 'fingerprint' or single property that sets them apart from others; therefore, they are identified through a combination of properties.

A mineral's physical properties are the result of its internal composition and atomic arrangement. This means the outward properties of the mineral are the result of its inner parts and organisation — for example, the way in which the atoms are bonded to one another influences properties such as lustre, streak and hardness.

The Mohs hardness scale, developed by Friedrich Mohs, is a numbered list of ten minerals ranked in order of hardness. Higher numbers correspond to harder minerals. The hardness of a mineral is determined by comparing it with the minerals or common materials in the Mohs scale. For example, a mineral that can be scratched by quartz but not by orthoclase has a hardness between 6 and 7.

Figure 7.10 shows that some more common materials can also be used to determine the hardness of a mineral.

FIGURE 7.10 The Mohs scale for testing the hardness of minerals



INVESTIGATION 7.1

Identifying mineral properties

Aim

To observe the properties of a range of minerals

Materials

- mineral kit
- common materials to substitute for unavailable Mohs scale minerals
- hand lens
- white ceramic tile

Method

1. Construct a table like the one in the results section to record your observations as you work through the following steps for each mineral.
2. Write down the mineral name and describe the colour and lustre.
3. Use the magnifying glass to look closely at the mineral and describe the shape and size of its crystal(s).
4. Scrape the mineral across the unglazed side of a white ceramic tile. Record the colour of the streak.
5. Use the Mohs scale minerals or the common materials (figure 7.10) to estimate the hardness of the mineral by trying to scratch it. An approximate range, such as 5–6, is sufficiently accurate.

Results

Complete your table for each mineral to present your results. Remember to add a title to your table.

Mineral	Colour	Lustre	Crystal shape and size	Streak	Hardness

Discussion

1. How similar were some of your minerals? Note two minerals that were close but had one or two different properties.
2. Other than those already described, what additional properties of minerals could be used to identify them?
3. If two unlabelled mineral samples have the same colour and lustre, can you be sure that they are the same mineral? **Explain** how you would find out.

Conclusion

What can you conclude about the properties across a range of minerals?

SCIENCE INQUIRY: Construct a flow diagram to help identify minerals

Using your data from investigation 7.1, construct a flow diagram to help identify minerals. Begin with a simple question, such as ‘Is the lustre metallic or non-metallic?’ From there, branch out by asking other questions, like ‘Does it leave a streak?’ or ‘Is it harder than glass?’ At various points in your diagram, the answers should lead to the identification of a specific mineral.

When constructing your flow diagram, make it clear and easy to follow by organising it into logical steps. Be creative with how you display the information — use boxes, arrows or symbols to make the process visually engaging. Remember, colour alone is not always a reliable characteristic for identifying minerals, so be sure to include multiple properties to make your diagram accurate and thorough.

Data and information can be organised and processed by selecting and constructing representations including tables, graphs, keys, models and mathematical relationships (VC2S8I04)

7.2 Activities

learn**on**

7.2 Quick quiz on	7.2 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 6, 9	3, 4, 7, 10	5, 8, 11, 12, 13

Remember and understand

1. Rocks are naturally forming, coherent combinations of what potential three substances? **Name** all three.
2. **Identify** whether the following statement is true or false. Large crystals are likely to form when there is a small amount of space available and the mineral grows quickly.
3. MC **Name** which materials are a mineral.
   A. Ice
   B. Salt
   C. Gold
   D. Glass
4. **Explain** what a mineral is.
5. **Explain** what a native element is. Provide two examples.
6. **Name** the largest group of minerals. What does their name say about their chemistry?
7. **Identify** the approximate hardness on the Mohs scale (to the nearest whole number) of a mineral that can be scratched by an iron nail but not by sandpaper.
8. **List** at least four properties that you could observe to help you identify an unknown mineral.

Apply and analyse

9. **Explain** the difference between a rock and a mineral.
10. A mineral can be scratched by a copper coin but not by a fingernail. Is the mineral quartz, fluorite or calcite?
11. You have two samples, each of a different mineral, but no other equipment to test them for hardness. How could you tell which mineral is harder? **Justify** your answer.
12. You have found a rock with tiny minerals in it and you would like to identify them. **Explain** how you could go about testing the physical properties to help you identify the minerals.

Evaluate and create

13. SI A geologist has been hired to find some haematite iron ore. In the field, they find lots of rocks. To determine if there is haematite present, they look for rocks with a dark colour and metallic lustre. They then pick it up to see how heavy it is. If it is dark coloured with a steel grey metallic lustre, and is very heavy, they call it haematite.
    a. **Recall** the method the geologist used to identify the mineral. Is anything missing?
    b. How reliable is their claim that the sample contains haematite? **Explain** your answer.
    c. **Suggest** what you could do to improve the conclusion.

Answers and sample responses are available in your digital formats.

LESSON 7.3 Mining for minerals

LEARNING INTENTION

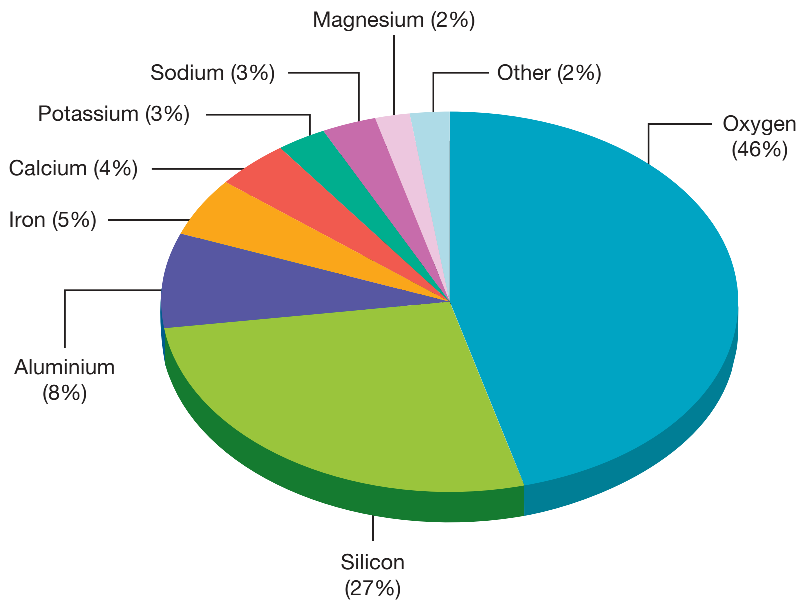
In this lesson you will explain mining processes, analyse its economic contributions and evaluate its environmental and societal impacts.

7.3.1 Metals in everyday life

Metals play a huge role in our daily lives. Phones contain metal components such as wires and lithium batteries. Cutlery, cars, bikes and even school buses are made from metal. These metals come from minerals found in rocks within Earth's crust.

The pie chart in figure 7.11 shows that almost three-quarters of Earth's crust (by weight) is made up of oxygen and silicon (non-metallic elements). Most of the time, the metallic elements, such as aluminium, iron, copper, nickel, silver and gold, combine with the non-metallic elements to form compounds within minerals.

FIGURE 7.11 The elements in Earth's crust. The metallic elements are relatively rare compared with oxygen and silicon.



Minerals that contain metals of value and can be mined for profit are called **ore minerals**. **Mining** is the process by which ore minerals are extracted from the crust. It is expensive and takes a lot of effort. Therefore, ore minerals must be concentrated in one location to make mining worthwhile. Finding these locations is no easy task.

Mining in Australia

Mining is a very important part of Australia's economy, contributing around 13.6 per cent of the nation's income in 2023 and supporting over 270 000 jobs, which is about 2 per cent of the total workforce. From 2010 to 2020, the mining industry generated over $132 billion in taxes, helping to fund essential public services such as healthcare and roads. In recent years, mining has continued to underpin the federal government's budget, with more than half of corporate tax revenue coming from this sector. However, the industry also faces challenges, such as workforce reductions, weather-related disruptions, market fluctuations and shifting global demand for resources such as copper.

While the economic contributions of mining are significant, its environmental impacts cannot be ignored. Mining activities often result in deforestation, habitat destruction and soil erosion. The extraction and processing of minerals can lead to air and water pollution if not managed responsibly. Moreover, abandoned mines can leave long-lasting scars on the landscape, posing challenges for rehabilitation.

Balancing these environmental concerns with economic benefits is essential. Sustainable mining practices, stricter environmental regulations and advancements in green technologies are increasingly being adopted to mitigate negative impacts. For Australia, finding this balance will ensure the mining industry continues to support the economy while minimising harm to ecosystems and local communities.

7.3.2 Mineral exploration

Finding ore minerals hidden below Earth's surface is a challenge. Geologists and geophysicists begin by using tools and techniques such as:

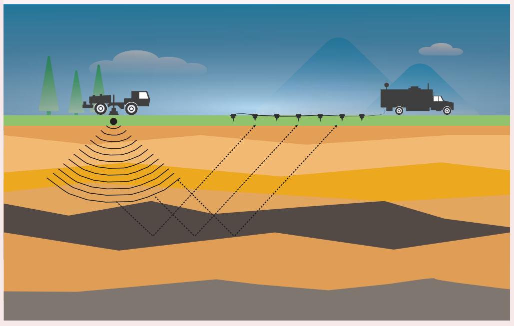
- *satellites*, which have on-board cameras, radar and sensors to help detect geological features likely to contain ore
- *magnetic surveys*, which detect minerals such as haematite iron ore from the ground or air, due to their magnetic properties
- *gravity surveys*, which map the distribution of density within the upper crust
- *seismic surveys*, which define geologic layers within the upper crust using the reflection of small seismic waves that are generated from large 'thumper' trucks
- *soil and water analysis*, which tests for traces of ore minerals washed into streams or lakes.

SCIENCE AS A HUMAN ENDEAVOUR: Looking for buried resources

Most of Australia's mineral, energy and water resources have been found in the exposed or shallow rocks of the crust that make up about 20 per cent of its area. Poorly exposed rocks under sedimentary basins or weathering profiles, or even the sea, may also contain resources. These concealed areas will be the focus of future exploration.

Government and industry scientists are adapting new technologies to explore for buried resources. Penetrative geophysical surveys collect data that is used in 3D modelling of Earth's sub-surface. Geophysical investigations include seismic, magnetic, electromagnetic and gravity surveys. These measure different rock properties, which are used in computer modelling. Geological, geochemical and groundwater data are also fed into models of the sub-surface.

FIGURE 7.12 Seismic survey technique used in resource exploration



The Australian Academy of Science is leading the government program UNCOVER, which involves many organisations. This program will use smart analytics and algorithms to simulate geological models and rock properties. New analytical software tools will use predictive technology, machine learning, geological uncertainty analysis and geoscience modelling to improve deep-Earth imaging, develop new exploration technology and support the future search for resources.

1. How do advancements in technology, such as machine learning and predictive analytics, improve our understanding of Earth's sub-surface?
2. Why is it important for scientists to develop new methods to explore concealed resources, such as those under sedimentary basins or the sea?
3. How does the use of 3D modelling and geophysical surveys represent a change in how resources are located compared to traditional methods?
4. What role do multidisciplinary teams (e.g. geophysicists, data analysts, geologists) play in programs such as UNCOVER?

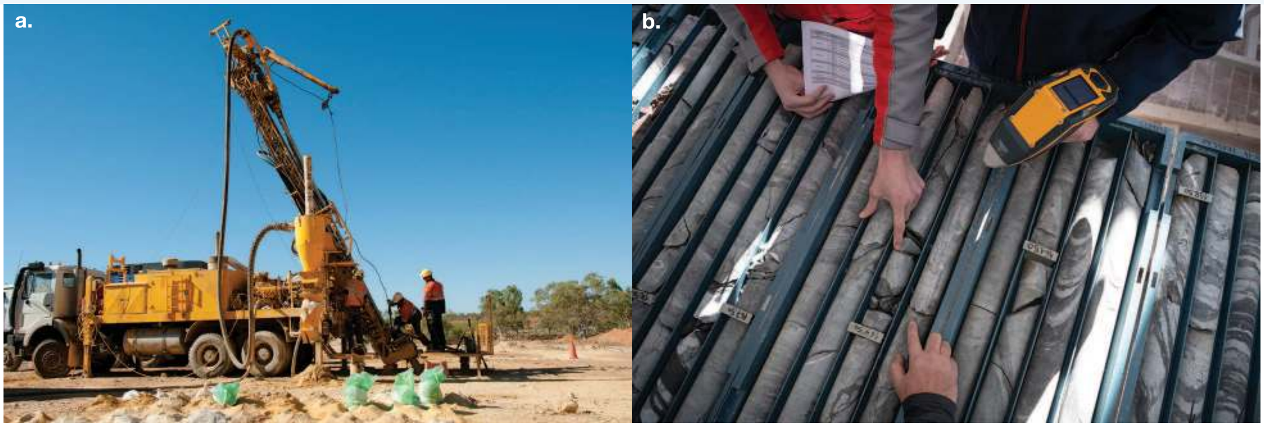
5. How might new evidence gathered from advanced exploration techniques challenge or change existing theories about Australia's geology or resource distribution?
6. What ethical or environmental considerations should be taken into account when exploring for resources in concealed or sensitive areas?

Scientific knowledge, including models and theories, can change because of new evidence (VC2S8H01)

If there is sufficient evidence that a mineral **deposit** exists, a licence must be obtained before any clearing is done or heavy drilling equipment is brought in.

Drilling allows mining companies to have a very detailed examination of what lies beneath the surface. Holes are bored into the ground and rock samples are removed for testing to confirm the presence of mineral deposits underground (figure 7.13). Mining companies are required by law to clean up exploration drill sites and ensure they are left to an acceptable standard. Landholders and Aboriginal and Torres Strait Islander Peoples representatives must also be consulted regarding access to land for exploration and mining.

FIGURE 7.13 a. A drill rig is boring a hole into the ground. **b.** A diamond drillcore is used to closely examine and measure rock and mineral properties.



7.3.3 Steps to Mining

1. **Planning and approval**
   Before mining starts, a company must prepare an **Environmental Impact Statement (EIS)**. The EIS outlines:
   - the local environment (plants, animals, soil, etc.)
   - the project's effect on the community and environment, including new roads and other developments
   - plans to reduce pollution and rehabilitate the land.
2. **Removing the ore**
   To obtain ore from the ground, it is often necessary to remove large amounts of rocks and soil. The way this is done depends on how close the ore deposit is to the surface.
   - **Open-cut mining** is used when ore is close to the surface. Vegetation, topsoil and waste rock (rocks that do not contain the ore minerals) are removed and kept aside.
   - **Underground mining** is used for deeper deposits. Shafts and tunnels are dug to reach and remove rocks containing the ore but are more dangerous and expensive.

   The development of open-cut and underground mining is overseen by mining engineers.

3. **Extracting the metal**
   Obtaining the metal element takes place in two stages.
   - **Mineral extraction** separates ore mineral from **gangue** rock by crushing, grinding and washing. Tailings are piles of the gangue materials.
   - **Metal extraction** separates the metal element from the ore using chemical reactions.

   Chemical engineers and metallurgists are involved in the design of these processes.
4. **Rehabilitation**
   Once mining is done, the land is carefully restored during the **rehabilitation** stage.
   - Seeds from local plants are collected before mining and grown in nurseries.
   - Waste rock is used to fill in mining holes, covered with topsoil, and shaped to fit the surroundings.
   - Vegetation is replanted to prevent erosion and restore the land for crops, grazing or wildlife conservation.

FIGURE 7.14 Resurfacing and replanting a former open-cut iron mine on Koolan Island, Western Australia

ACTIVITY: Rehabilitation ideas

Objective

Students will explore how mining impacts local environments and propose simple rehabilitation ideas.

Instructions

1. Research and brainstorm (10–15 minutes)
   - Split students into small groups.
   - Each group brainstorms one environmental impact of mining (e.g. habitat destruction, water pollution) and one possible rehabilitation strategy (e.g. replanting trees, restoring habitats).
2. Group sharing (10 minutes)
   - Each group shares their impact and rehabilitation idea with the class.
   - Encourage brief discussions about how realistic and effective their ideas are.
     - Why is rehabilitation important after mining?
     - How can mining balance environmental care with economic needs?

INVESTIGATION 7.2

Searching without disturbing

Aim

To model the search for minerals below the ground

Materials

- a tray of sand
- 10 paperclips
- blindfold (optional)
- compass
- paper and clipboard-ruler

Method

1. Find a partner. Each of you should then draw identical maps of the sand tray. Use a ruler to construct a grid on each map. Label the grids across the top and down the side (e.g. A–J across the top, 1–15 down the side). Each grid should consist of at least 100 equal-sized rectangles or squares.
2. Without showing your partner, hide the paperclips in the tray of sand and mark the location of the 10 clips on your map.
3. Your partner's task is to locate the 10 paperclips and mark them on the map without disturbing the sand. You might wish to set a time limit.
4. Swap roles and repeat the steps above.

Results

1. What property of the paperclips allowed them to be located?
2. Record the number you found and where you found them onto your grid map.

Discussion

1. How could your predictions of the location be checked with a pencil?
2. What was your success rate?
3. After checking, can the sand be restored to its initial condition?

Conclusion

Summarise your findings from this investigation about searching for hidden metals.

7.3 Activities

learnon

7.3 Quick quiz on | **7.3 Exercise**

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 5, 8	3, 6, 9, 10	4, 7, 11

Remember and understand

1. **State** where minerals are found.
2. **State** where in Earth's crust the metal elements are most commonly found.
3. **Describe** the method of open-cut mining for removing mineral ores from the ground.
4. **Outline** the two stages involved in obtaining a metal element from rock.
5. **State** what EIS stands for.
6. **Outline** the information that is included in an EIS.

Apply and analyse

7. **Explain** how mining companies rehabilitate the land used for mining.
8. **Explain** why it is important to recycle metals as much as possible.
9. The most common element in Earth's crust is oxygen. This element is a gas except at extremely low temperatures. **State** in what form oxygen is found in Earth's crust.

Evaluate and create

10. In a table like the one provided, **list** the benefits and disadvantages of mining.

Benefits	Disadvantages

11. **Discuss** reasons for and against allowing mining to take place in Australia's national parks.

Answers and sample responses are available in your digital formats.

LESSON 7.4 Igneous — the 'hot' rocks

LEARNING INTENTION

In this lesson you will describe the types of environments that igneous rocks form in and how they can be classified according to their composition and texture.

7.4.1 How rocks are formed

The rocks you can see have formed in Earth's **lithosphere** (see figure 7.15), which includes Earth's crust and the top part of its mantle. Rocks are classified into one of three groups based on how they formed: **igneous**, **sedimentary** or **metamorphic rocks** (table 7.1).

FIGURE 7.15 The rocks you can see have formed in Earth's lithosphere.

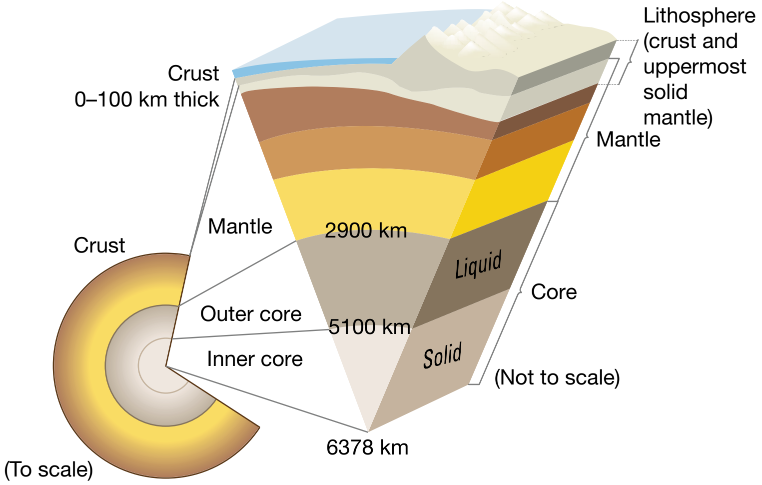


TABLE 7.1 The three types of rocks and how they formed

Igneous rocks	Sedimentary rocks	Metamorphic rocks
If the right temperature and pressure conditions are met, rocks can melt into **magma**. New rocks are formed when magma *cools and solidifies*.	When rocks are exposed on the surface, the presence of water, air and life helps to both physically and chemically break them down. This is called **weathering**. New rocks can form, as **erosion** and **deposition** create layers of **sediments**; this can include the remains of living things that are hardened by *compaction* as more and more layers of sediment are added.	Rocks can be buried to great depths, where the higher temperatures (greater than 200 °C) and pressures can cause the rock to change form. Both the mineral type and appearance can change. The change happens in the solid state, meaning there is no melting.

Melting rock

There are places around Earth where physical conditions allow rocks to melt or partially melt deep underground. The molten rock underground is called magma, and it rises slowly towards the surface. If the magma breaks through and flows onto the surface it is then called **lava**. Rocks that form from the cooling of magma below the surface or lava on the surface are called igneous rocks.

The appearance of all igneous rocks depends on:
1. how quickly the lava or magma cooled
2. what substances it is made of.

KEY IDEA

The word 'igneous' comes from the Latin word *ignis*, meaning 'fire'. The words 'ignite' and 'ignition' also come from the same Latin word.

EXTENSION: Is the interior of Earth all liquid?

At Earth's surface, rock begins to melt when heated between 800 and 1000 °C, and will be completely melted at about 1200 °C. However, if you put a rock under pressure, it becomes stronger and requires a higher temperature to melt. This is why the interior of Earth is mostly hot solid material and not all molten rock, despite the fact that temperatures of greater than 1000 °C exist.

The physical conditions required to melt rock would be:
1. adding so much heat that it overcomes the pressure
2. releasing pressure from a hot rock
3. adding fluids, such as water.

Releasing pressure and adding fluids lower the melting temperature. Magma is generated only where one or more of these conditions are met.

7.4.2 Extrusive rocks

Lava is released from erupting volcanoes at temperatures of 1000 °C or more. At that temperature, flowing lava could take hours to weeks to cool down and become solid rock. However, if lava is ejected into the air from explosive volcanoes, it cools almost instantly. The lava erupting from underwater volcanoes on the ocean floor also cools quickly.

Igneous rocks that form from the cooling of red-hot lava on Earth's surface or lava spilling from underwater volcanoes are classified as **extrusive** or volcanic. Features of extrusive rocks are summarised in table 7.2.

FIGURE 7.16 Red-hot lava flowing on Earth's surface. The cooling of lava forms a crust that can shift with the continued movement of underlying lava, creating a ropey look.

TABLE 7.2 Features of extrusive igneous rocks

Crystal size	Rock colour
The size of crystals in extrusive igneous rocks is generally very small because of how fast the lava cools. When it cools quickly, there is not enough time for large crystals to form.	Colours range from black to grey, white or even red. The colour reflects the types of minerals that have formed. Generally, the dark rocks are rich in iron (Fe) and magnesium (Mg) minerals. The lighter coloured rocks contain more minerals that are richer in silicon (Si).

Basalt and rhyolite

Basalt is a common extrusive rock that is dark coloured with small mineral crystals. You may be able to see some of the small crystals, but most require a magnifying tool. If basalt forms from lava cooling in cold ocean water, the crystals will be even smaller and only visible under a microscope. Why do you think that is so?

When rocks are heated up they expand, and when they cool down they contract (shrink). The basalt in figure 7.17 (and in the image opening this topic) formed from a cooling basalt lava flow. During cooling, the new rock contracts and this can form vertical columns of basalt. Beware of these columns on a cliff, as they can topple over.

FIGURE 7.17 When basalt flows cool, they can form hexagonal columns.

Rhyolite is another common extrusive rock. It also generally has small crystals, but, unlike basalt, it is light coloured due to having more silica-rich minerals. More silica-rich minerals make the lava sticky and harder to flow — a term used to describe this is called **viscosity**. A good example of different viscosities is honey versus water. Water flows over a table easily (low viscosity), but honey poured over the same table will move a lot slower (high viscosity). Because the rhyolite lava is viscous, it does not travel far from the volcano. Basalt has a lower viscosity and can flow further from a volcano.

FIGURE 7.18 Basalt and rhyolite are both extrusive rocks. Basalt is dark coloured (left) and rhyolite is light coloured (right).

Scoria, pumice and obsidian

Some violent volcanic eruptions shoot out lava filled with gas. The lava cools very quickly while it is still in the air and traps the gas inside. Rocks that form this way are full of holes from where the gas was trapped. Two examples of this type of rock are **scoria** and **pumice**.

TABLE 7.3 Features of explosive igneous rocks

Scoria	Pumice
Scoria is a dark (black, reddish-brown or grey) volcanic rock full of holes. It has a darker colour because it contains more iron. It is usually found closer to a volcano's crater. 	Pumice is a pale-coloured volcanic rock. It is very light because it is mostly made of glass and full of holes. Pumice floats on water and sometimes washes up on beaches thousands of kilometres from where it erupted! 

Obsidian is a smooth, black rock that looks like glass because it is a natural volcanic glass. It is formed when silica-rich lava cools almost instantly. Glass is not a mineral because, as it cools so quickly, it does not have a crystal structure.

The unique, curved way in which obsidian fractures when struck, combined with its hardness, makes it a good material to manufacture sharp, blade-like edges. For this reason, obsidian has been used as cutting tools and arrowheads throughout history. Rock technology is explored further in lesson 7.8.

Although obsidian is usually dark in colour, it is extremely rich in silica and is mostly glass, like pumice. Pumice is a light grey colour because the visible holes stretch the glass, allowing light to refract and diffuse. Obsidian commonly lacks these holes, so it looks darker in colour.

FIGURE 7.19 The glassy extrusive igneous rock known as obsidian

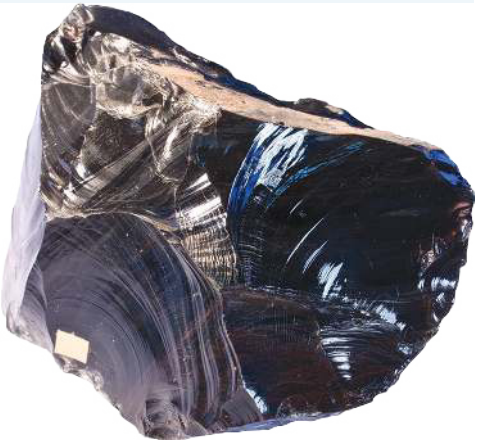


FIGURE 7.20 An obsidian arrowhead

7.4.3 Intrusive rocks

Igneous rocks can also form as magma cools below Earth's surface. These rocks are called **intrusive**. They cool very slowly (thousands of years or more) and become visible only when the rocks and soil above them are removed by erosion, or if people drill down into them. Intrusive rocks (sometimes called plutonic rocks) have larger crystals than extrusive rocks because the crystals had more time to grow. Large bodies of intrusive rock are called **batholiths**; they cover an area of over 100 km^2.

FIGURE 7.21 If a batholith is exposed to the environment, it will start to wear away along the cracks, which can leave large, rounded boulders called tors balancing on the surface. Over time, the batholith may break down completely. The breakdown of rocks is called weathering.

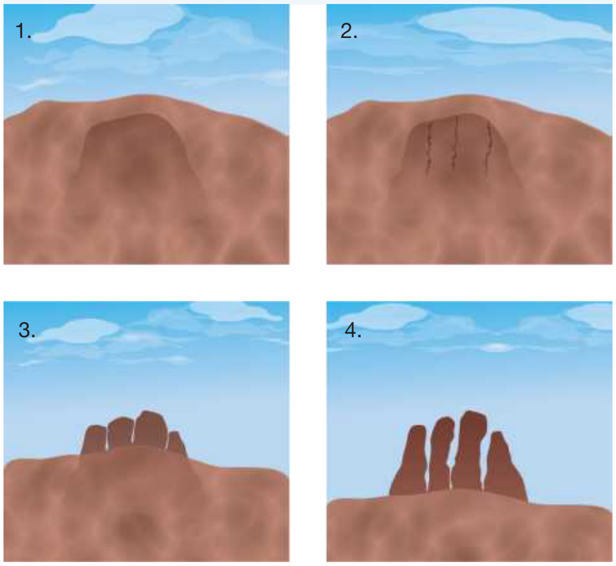
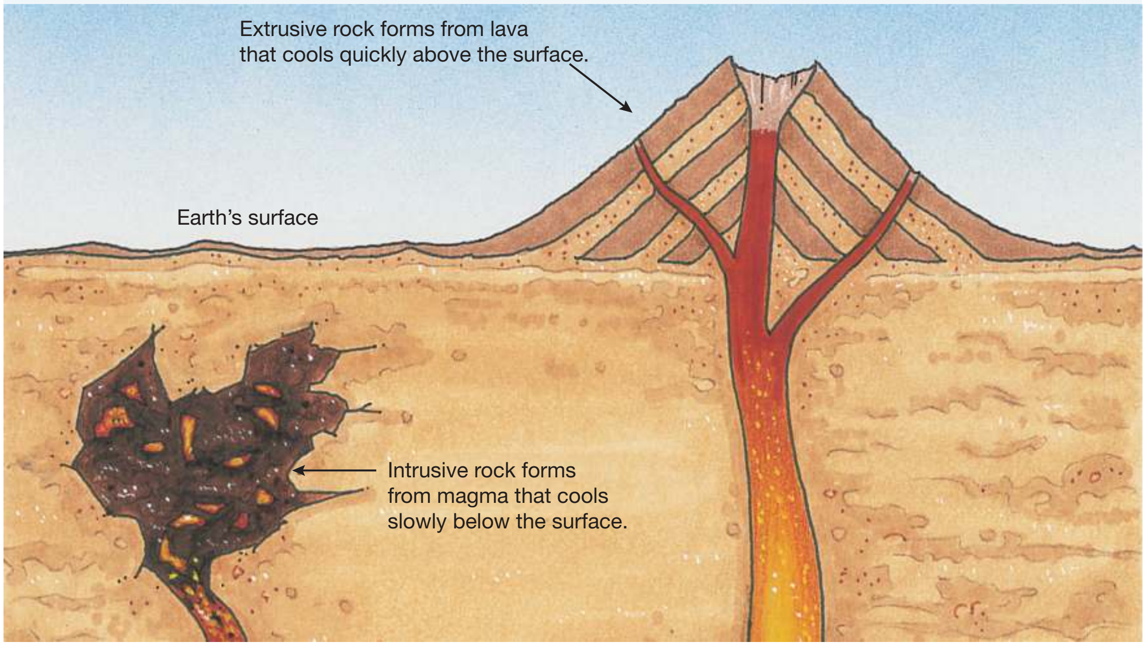


FIGURE 7.22 Igneous rocks can form below or above Earth's surface. Where they form will determine the speed of cooling and thus the crystal size.



Granite and gabbro

Two common intrusive igneous rocks are **granite** and **gabbro**. The crystals in both form over long periods of time and grow large enough to be easily seen without magnification. Being able to see the individual crystals makes it easier to identify the type of minerals present.

TABLE 7.4 Features of intrusive granite and gabbro rocks

Granite	Gabbro
Granite is a light-coloured intrusive rock with silica-rich minerals. The crystals found in granite are a mixture of white, pink, clear to grey and black minerals. These minerals are (in order of most abundant to least): • *feldspar* (white and pink) • *quartz* (clear to grey) • *mica* (black). Granite is the most common igneous rock found in the continental crust. 	Gabbro is a dark-coloured intrusive rock with minerals rich in iron (Fe) and magnesium (Mg). It looks mostly black, but if you look close enough, you will see some white and green. These minerals are (in order of most abundant to least): • *pyroxene* (black) • *feldspar* (white) • *olivine* (green). Gabbro is the most common igneous rock found in the oceanic crust. 

INVESTIGATION 7.3

Does fast cooling make a difference?

Aim

To investigate the effect of the cooling rate on the size of crystals

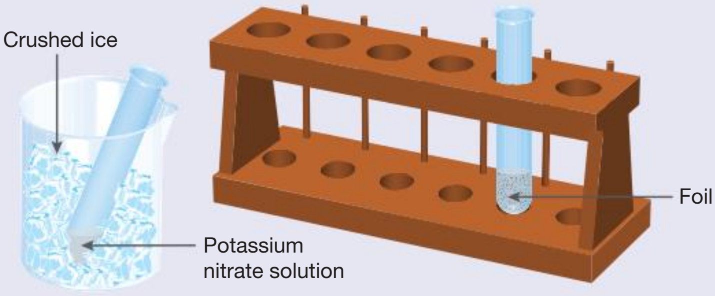
Materials

- freshly made saturated solution of potassium nitrate
- potassium nitrate
- spatula
- 250-mL beaker
- 3 test tubes and test-tube rack
- test-tube holder
- Bunsen burner, heatproof mat and matches
- crushed ice
- foil
- safety glasses
- hand lens

CAUTION: Safety glasses must be worn during this experiment.

Method

1. Half-fill a beaker with crushed ice.
2. Quarter-fill a clean test tube with saturated potassium nitrate solution. Add a spatula of potassium nitrate.
3. Gently heat the solution over a Bunsen burner flame until the added potassium nitrate has dissolved or until the solution starts to boil.
4. Pour half the warm solution into one clean test tube, and then the remaining half into another.



5. Place one test tube in the beaker of crushed ice. Wrap the bottom of the other test tube in foil and place it in the rack to cool.
6. When crystals have formed in each test tube, examine them with a hand lens.
7. Cool one solution quickly and the other one slowly.

Results

1. Draw a labelled diagram of some crystals in each test tube, concentrating on their shape and size.
2. Which test tube contained the larger crystals: the one that cooled quickly or the one that cooled slowly?

Discussion

1. Which types of igneous rock would you expect to have the larger crystals: those that cool slowly underground or those that cool quickly on the surface?
2. Which types of rock are represented by the two different test tubes?
3. Why do safety glasses need to be worn during this experiment?

Conclusion

Summarise your findings from this investigation, commenting on the relationship between cooling rates and crystal size.

7.4.4 Useful igneous rocks

Igneous rocks can sometimes host valuable ore minerals but they are also used in several other ways, as summarised in table 7.5.

TABLE 7.5 Uses of igneous rocks

Igneous rocks	Example of modern uses
Basalt	Basalt blocks have been used as a decorative building material. It is also commonly crushed and used for road base, asphalt and concrete.
Scoria	A reddish-brown or grey rock that can be crushed and used in garden paths or as a drainage material around pipes. It is also used in high-temperature insulation.
Pumice	Powdered pumice is used in some **abrasive** cleaning products. It is also used in chemical spill containment, water filtration, horticulture and cement manufacturing.
Granite and gabbro	Commonly used in building due to their strength and beauty. Granite or gabbro that has been polished to give it a glossy finish is also used for grave headstones, benchtops and statues or other monuments.

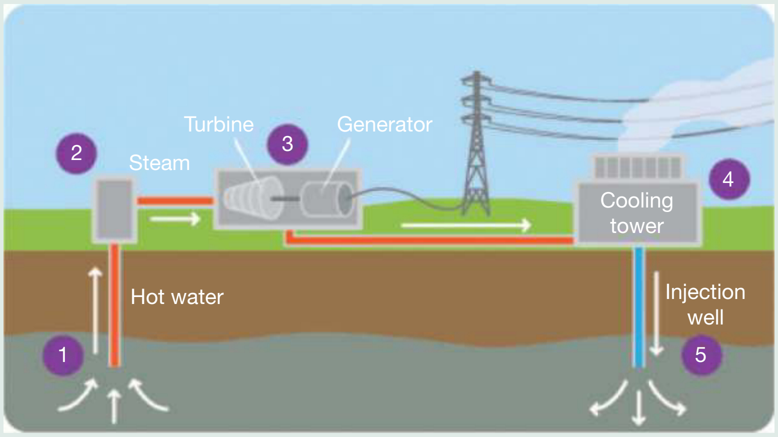
DISCUSSION

Locate a building, statue or memorial in your area that is made from igneous rock. Describe the rock in the structure, and suggest why it was the chosen material.

EXTENSION: Renewable geothermal energy in Australia

Geothermal energy is heat contained within Earth. Australia has great potential for geothermal energy to be used for generating electricity (figure 7.23). Geoscience Australia has calculated that there is sufficient energy contained within the Australian crust around hot rock systems that, if only one per cent of the resource were used, it would provide 26 000 years worth of electricity.

FIGURE 7.23 How heat from Earth can be used to generate electricity

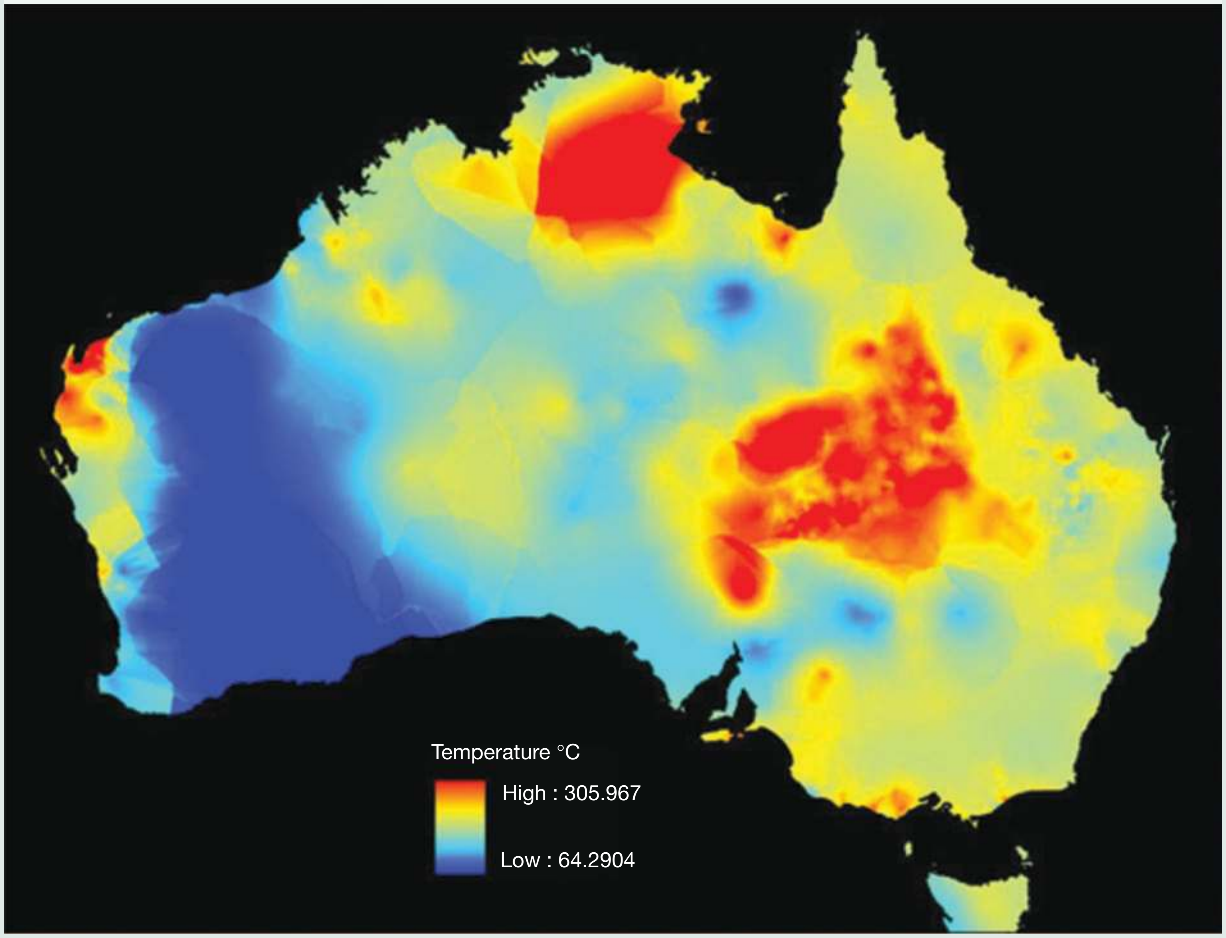


1. Hot water is pumped from deep underground through a well under high pressure.
2. When the water reaches the surface, the pressure is dropped, which causes the water to turn into steam.
3. The steam spins a turbine, which is connected to a generator that produces electricity.
4. The steam cools off in a cooling tower and condenses back to water.
5. The cooled water is pumped back into the Earth to begin the process again.

The hot rock systems in Australia are normally associated with bodies of granite rock 3–5 km deep that contain unusually high concentrations of the naturally radioactive elements uranium (U), thorium (Th) and potassium (K). The radioactive decay of these elements generates heat that is insulated by the rocks above them. Figure 7.24 is a model of the temperature of the crust at 5 km depth. The thicker the insulating layer, the hotter the temperature.

For the system to be complete as a geothermal energy source, there also needs to be a fluid circulating through the rock above to transport heat to the surface.

FIGURE 7.24 Modelled crustal temperature at 5 km depth



While significant hot rock systems have been identified, there is no present commercial production of geothermal energy in Australia.

- How would exploration be conducted to find these hot rock systems?
- According to the modelled crustal temperatures at 5 km depth, where are the potential hot rock systems?
- What sort of challenges are limiting access to this substantial renewable energy source?

7.4 Activities

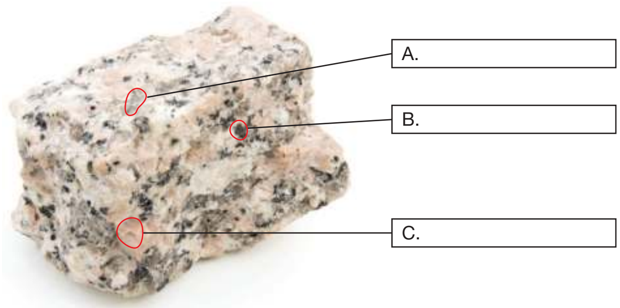
learnon

7.4 Quick quiz on	7.4 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 4	5, 6, 7, 8	9, 10, 11, 12

Remember and understand

1. MC How do igneous rocks form?
   A. They are created by layering and compacting sediments over time.
   B. They form when molten rock (magma or lava) cools and solidifies.
   C. They are shaped by wind and water erosion.
   D. They develop from fossils buried deep underground.
2. **Explain** what the varying colours of igneous rocks represent.
3. **Explain** what causes the frothy (holey) appearance of pumice and scoria.
4. Label the three minerals found in granite.
5. **Describe** two major differences between the appearance of granite and basalt.



Apply and analyse

6. **Compare** how extrusive and intrusive igneous rocks form.
7. **Explain** why the crystals in basalt that formed under water are smaller than those in basalt that formed on land.
8. Batholiths form well below the ground. **Explain** how they become visible on Earth's surface.
9. **Discuss** how you would decide that an igneous rock formed from a volcanic eruption.
10. Rhyolite is an extrusive rock that contains the same minerals as granite. **Describe** in what way you would expect it to be different from granite.

Evaluate and create

11. SI Geologists like to use classification tables like the one shown to identify relationships between different rock types and their properties.

	Silica rich	Iron and magnesium rich
Extrusive		
Intrusive		

   a. Complete this igneous-rock classification table by adding the names basalt, granite, rhyolite and gabbro into their proper locations.
   b. **State** where scoria, pumice and obsidian would go.
   c. **State** what you could add to your table to include these rocks and identify what makes them different.
12. If you came across an igneous rock that had a mixture of large crystals surrounded by small crystals, **suggest** how it may have formed.

Answers and sample responses are available in your digital formats.

LESSON 7.5 Sedimentary — the 'deposited' rocks

LEARNING INTENTION

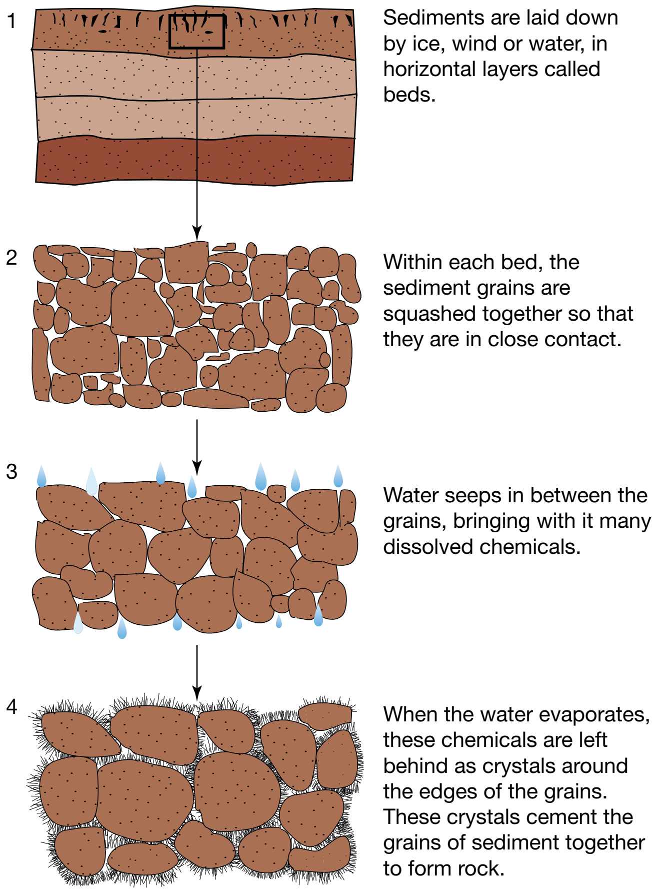
In this lesson you will describe how sedimentary rocks are formed and classified, and that they form in layers that record time and changes to Earth's surface.

7.5.1 Weathered, eroded, deposited and lithified

Rocks that are formed from weathered, eroded, deposited and lithified sediments are called **sedimentary rocks**. Each of these processes can be described as follows.

- Rocks exposed on the surface are physically or chemically broken down by weathering as the rocks are exposed to the atmosphere, water and living things.
- The weathered particles are then transported by wind, running water, waves or flowing glacial ice as sediment. This process is called erosion.
- When the agents of erosion slow down or stop moving, their capacity to transport sediments reduces and the sediments settle onto the surface. This settling is called deposition. Deposits of dead plants and animals are also sediments.
- Sediments will deposit one on top of another, which creates layers, or beds. As beds continue to deposit, the individual sediments are packed closer together by compaction. Water with dissolved minerals can also seep around the sediment. As the water between the fragments escapes due to increased compaction, the minerals that are left behind act like cement forming a sedimentary rock. Compaction and cementation help to **lithify** the beds into rock (figure 7.25).

FIGURE 7.25 Lithification — turning sediments into rock



Deposition environments

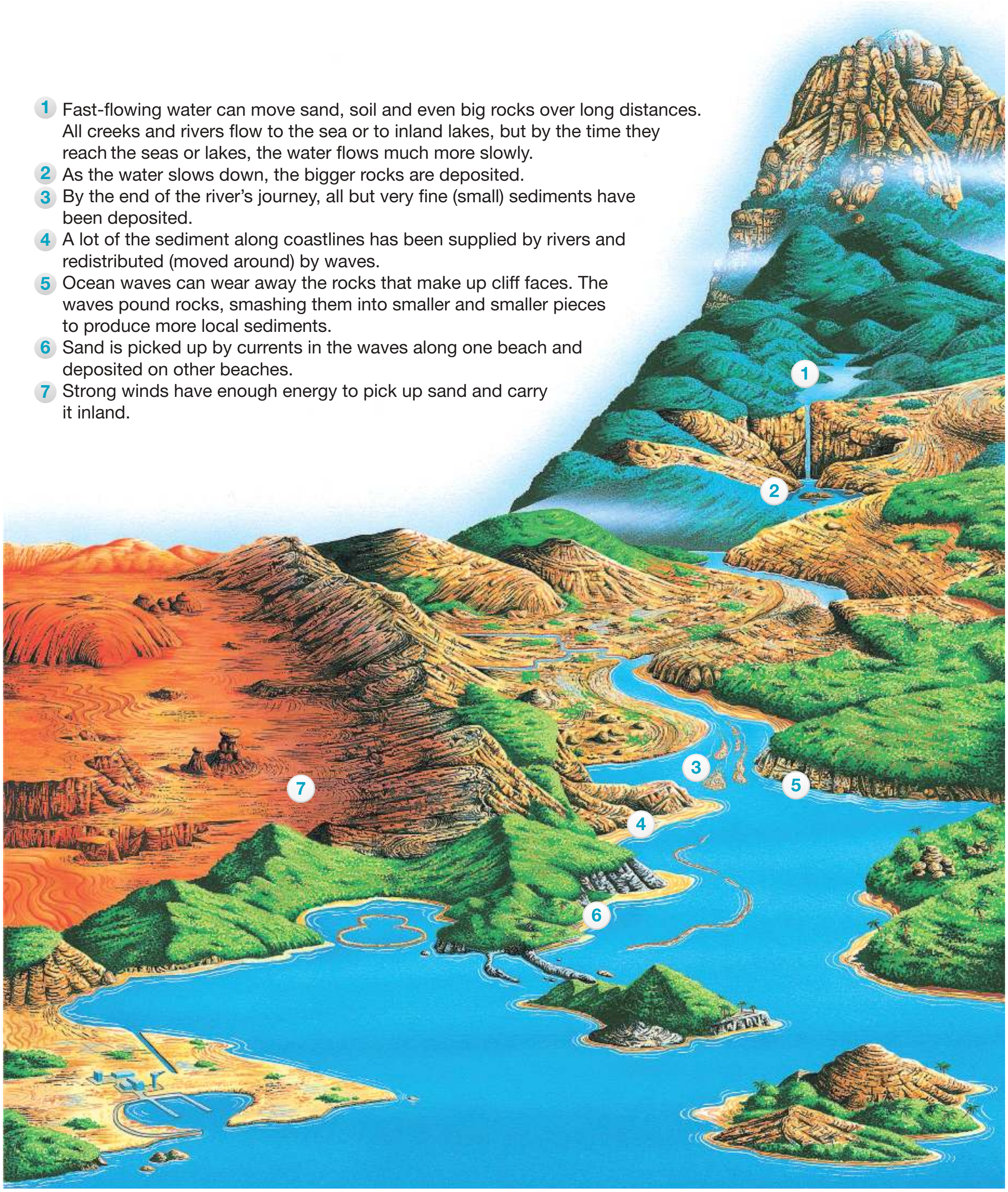
Sand deposited by the wind forms sand dunes, especially in coastal areas where sand is picked up and blown inland until it is stopped by obstacles such as rock or vegetation.

A fast-moving river is likely to carry sand, gravel and smaller particles. As it slows down on its path to the sea, the river loses energy and will deposit along the river channel. The larger particles, such as gravel and sand, settle first. By the time the river reaches the sea, it is usually travelling so slowly that only the very fine silt and mud particles remain to settle and help form **deltas**.

During floods, when rivers break out of their channels, sediments are deposited on flat, open land alongside the river. These plains are called **floodplains**.

In the coldest regions of Earth, especially at high altitudes, bodies of ice called **glaciers** slowly make their way down slopes. They move between several centimetres and several metres each day. Being solid, glaciers can push boulders, rocks, gravel and smaller particles down the slope. As the glacier melts it can deposit these sediments along the margins of the glacier.

FIGURE 7.26 Most sedimentary rocks are formed from weathered rock that has been transported and deposited by moving water (rivers and ocean).



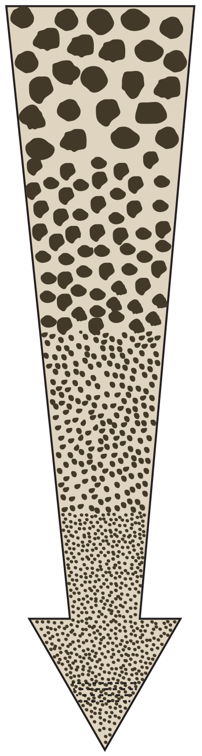
DISCUSSION

A common and fun activity on a warm summer day or weekend is to go to the beach, but where does all that sand come from? Is it a deposition environment? As a class, or in small groups, discuss where you think the sediment on beaches comes from. Consider whether all beaches have the same size and type of sediment.

7.5.2 Clastic sedimentary rocks

Sedimentary rocks are initially classified based on what they are made of. The most common group is clastic sedimentary rocks, which are made of fragments/sediments of weathered and eroded pre-existing rocks. These fragments are known as clasts.

TABLE 7.6 The names of clastic sedimentary rocks are based on their grain size.

Sediment clast size	Clastic sedimentary rock names
	**Conglomerate** contains large clasts surrounded by sediments of different sizes, all cemented together.
	Sandstone is formed from grains of sand that have been cemented together.
	Siltstone particles are smaller than sand, but slightly larger and not as soft as those in mudstone.
	Mudstone and **shale** are formed from muddy particles (clay and silt) deposited by calm water. Shale shows tiny layers of clay (represented by short, horizontal lines), whereas mudstone is a thicker bed of clay.

KEY IDEA

Conglomerate is formed from sediments that might be deposited by a fast-flowing or flooded river. The word 'conglomerate' comes from the Latin word *conglomerare*, meaning to 'roll together'.

FIGURE 7.27 A conglomerate

INVESTIGATION 7.4

Sediments and water

Aim

To investigate the order in which different sediments are deposited

Materials

- mixture of garden soil, gravel, sand and clay
- large jar with lid
- watch or clock

Method

1. Before commencing this experiment, form your own hypothesis about the order in which the different types of particles will settle. Give reasons for your hypothesis.
2. Draw a diagram to illustrate your hypothesis.
3. Place enough of a mixture of garden soil, gravel, sand and clay in a large jar to quarter-fill it.
4. Add enough water to three-quarter fill the jar and place the lid on firmly. Shake the jar vigorously.
5. Put the jar down and watch carefully as particles begin to settle. Note the time taken for each layer of sediment to settle completely.
6. Leave the jar for a day or two. Then compare your observations of the jar with your diagram.

Results

Record your answers to the following tasks to present your results:

1. Draw a labelled diagram showing clearly any layers that form. Identify the layers if you can.
2. Which type of sediment settled first?
3. Where are the other particles of sediment while the first layers are settling?
4. Which sediments settled after a day or two?

Discussion

1. Why did the last sediments take so long to settle?
2. Was your hypothesis supported by your observations?
3. What is the relationship between the size of sediment particles and the time taken to settle?

Conclusion

Summarise your findings from this investigation about the order that different sediments are deposited.

7.5.3 Sedimentary rocks from living things

Limestone is a sedimentary rock that is formed from deposits of the remains of sea organisms such as algae, brachiopods and corals. The remains of some of these organisms are still visible as **fossils** in limestone, while others are microscopic. The skeletal hard parts of these dead animals contain calcium carbonate (the mineral calcite). When the organisms die, fragments of their skeletons deposit as sediments and are cemented together over a period of time.

Coal is sedimentary rock formed from the remains of dead plants that are buried by other sediments. In dense swamps, layers of dead trees and other plants build up. If these layers are covered with water before rotting is completed, they can be buried by other sediments. The weight of the sediments above compacts the partially decayed plant material. Over millions of years, the compaction and heating squeezes out the water, forming coal.

FIGURE 7.28 Limestone is commonly made of marine fossils. Colours can range from white and tan to red and dark grey.

FIGURE 7.29 Coal is formed form the remains of dead plants.

CASE STUDY: Chalk

Chalk is a type of limestone that is not very hard. Chalk is formed from microscopic plankton made of calcium carbonate that separate from seawater and settle to become a white, muddy sediment on the sea floor. The sediment hardens and compacts over time to form chalk. This process takes millions of years. The remains of other sea creatures are also found in the sediment that forms chalk.

FIGURE 7.30 The white cliffs of Dover that overlook the English Channel are composed of chalk.

7.5.4 Chemical sedimentary rocks

Some sedimentary rocks form when water evaporates and leaves behind precipitated mineral crystals that can be compressed and buried by other sediments. **Rock salt** is an example of a rock formed in this way. It forms from residues of salt that remain after the evaporation of water from salt lakes or dried-up seabeds, and can form beds that are hundreds of metres thick.

7.5.5 Rocks in layers

Layers of sedimentary rock are often clearly visible in road cuttings and cliffs (figure 7.31). Not only do the layers help you identify them as sedimentary rock, but they are also records of time, with the bottom layers older than the top layers.

KEY IDEA

The sedimentary rock layer can help determine a fossil's age.

Sedimentary rock layers are originally deposited flat (horizontal). However, layers of sedimentary rocks below Earth's surface can be affected by the same forces that form mountains. These forces can bend and tilt the rock layers into incredible folds (figure 7.32).

FIGURE 7.31 The cliffs bordering the King George River, in the Kimberley region of Western Australia, are a spectacular example of exposed sedimentary rock layers that have been cut into by erosion of a fast-flowing river.

FIGURE 7.32 These layers of limestone formed on the ocean floor and were originally horizontal, but have since been folded by large mountain-building forces.

7.5.6 Useful sedimentary rocks

TABLE 7.7 Uses of sedimentary rocks

Sedimentary rock	Examples of modern uses
Sandstone, limestone and shale	Sandstone and limestone are often used as external walls of buildings. These sedimentary rocks are well suited to carving into bricks of any shape. Shale can be broken up and crushed to make bricks.
Limestone	Limestone is broken up to produce a chemical called lime. Lime is used to make mortar, cement and plaster, and is used in construction for walls and paving. It is also used in the treatment of sewage and in agriculture to neutralise acid in the soil.
Rock salt	Rock salt is used on roads and driveways in very cold areas to combat ice. It is also used as a type of seasoning for food.
Coal	Coal is used in steel-making and cement manufacturing, and in electricity generation. It is burned in electric power stations to boil water. The steam is then used to drive the turbines that produce electricity. In some countries, coal is burned in home heaters, although this can cause air-quality problems. Coal is a non-renewable energy source because it is not replenished within our lifetime; in fact, it takes millions of years to form a layer of coal.

INVESTIGATION 7.5

Identifying sedimentary rocks

Aim

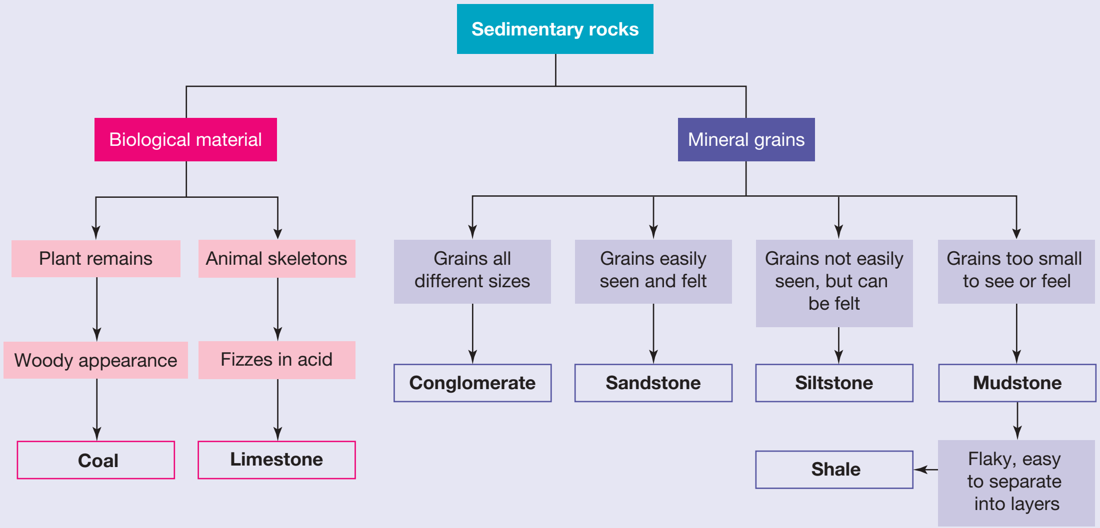
To use a key to identify a variety of sedimentary rocks

Materials

- several examples of unlabelled sedimentary rocks, including limestone
- dropping bottle of dilute hydrochloric acid

Method

1. Use the following key to identify the samples of sedimentary rocks you have been given.
2. To do the acid test, just add one drop of dilute hydrochloric acid onto the sample and wipe off with a clean paper towel.



Results

Design a table to record your answers for each step in identifying each sample, particularly the name at the end.

Discussion

1. How many of the unlabelled rocks did you confidently identify?
2. Which of the rock samples were the most difficult to identify, or which are you least confident about?
3. Discuss why it was difficult and how the key might be improved.

Conclusion

What can you conclude about identifying sedimentary rocks?

7.5 Activities

learnon

7.5 Quick quiz on	7.5 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 8, 11, 12	4, 5, 9, 13, 15	6, 7, 10, 14

Remember and understand

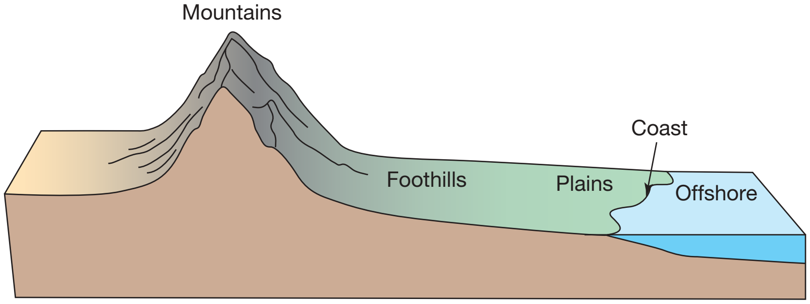
1. MC What are all sedimentary rocks formed from?
   A. Cooled lava from volcanic eruptions
   B. Layers of compacted sediments like sand, mud and organic material
   C. Melted minerals that harden deep underground
   D. Crystals growing in high-pressure conditions
2. **List** in order the process of forming a sedimentary rock.
3. **Name** what clastic sediments are before they eventually form a clastic sedimentary rock.
4. As a flooded river slows down, **identify** which particles are likely to settle first: gravel, sand or fine clay.
5. **Explain**, with the aid of a diagram, how sediments lithify and become a sedimentary rock.
6. Clastic sedimentary rocks formed from weathered pieces of other rock are classified based on what characteristic?
7. **Explain** how a floodplain is created.
8. **Name**, in which type of sedimentary rock, you would most likely find embedded seashells.
9. **Describe** how coal is formed.

Apply and analyse

10. **Explain** why sedimentary rocks are found in layers.
11. **Explain** why limestone and coal are sometimes referred to as 'biological rocks'.
12. A road cutting reveals a layer of sandstone beneath a layer of mudstone. Between them is a much thinner layer of conglomerate.
    a. **State** which layer would have formed from sediments deposited in a low-energy environment, such as a lake.
    b. **State** which layer would have formed while the area was flooded by a swollen, fast-flowing river.
    c. **State** which layer would have formed while the area was near a delta and coastline.
    d. **State** which layer was formed most recently.

Evaluate and create

13. **Discuss** what type of sediment you would expect to find on the bed of the Yarra River in Melbourne.
14. SI **Explain** how the clast size for sediment deposits would change in a classic path from mountain to coastline to just offshore.



15. **Compare** peat, brown coal and black coal. What do they have in common? How are they are different from each other?

Answers and sample responses are available in your digital formats.

LESSON 7.6 Metamorphic — the 'changed' rocks

LEARNING INTENTION

In this lesson you will describe how some common types of metamorphic rocks form, and what clues they provide to past environments.

7.6.1 Stability and change

So far you have learned that rocks melt and solidify, with some even blasted out of a volcano to solidify on the surface. On Earth's surface, rocks weather and erode to form sediment, which end up depositing and lithifying over time. What else can happen?

Earth never stops changing. As rocks are put under new conditions (such as increasing temperature and/or pressure with deep burial or during a mountain-building event) they can 'morph' into another kind of rock — a metamorphic rock.

KEY IDEA

The word 'metamorphic' comes from the Greek words *meta*, meaning 'change', and *morph,* meaning 'form'.

This change occurs because every mineral forms in a specific set of physical and chemical conditions. When those conditions change, the mineral changes physically and/or chemically to be stable under the new set of conditions. All of this change can happen without melting and is called **metamorphism**.

- A physical shift can occur when the mineral rotates into a new orientation.
- A chemical shift can occur when either the mineral breaks down to form new minerals or crystal structures realign — such as we saw in the formation of diamonds in section 7.2.2.

7.6.2 Metamorphic rocks

Rocks pushed deep below Earth's surface are buried under the weight of the rocks, sediments and soil above them. They are also subjected to higher temperatures with increasing depth. On average, the temperature increases by about 25 °C for every kilometre below the surface. Added heat and pressure can change the type and appearance of the minerals in rocks.

Any kind of rock (igneous, sedimentary or metamorphic) can undergo metamorphic changes due to increased heat and/or pressure. The changes that take place during the formation of metamorphic rocks depend on:

- the type of original rock
- the amount of heat
- the type and amount of pressure applied
- how quickly the changes take place.

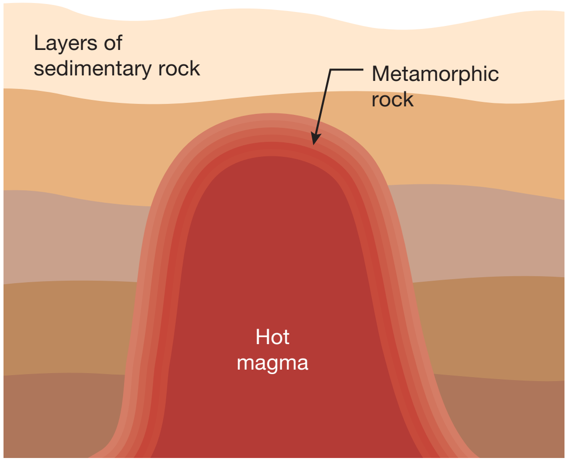
The higher the amount of heat and/or pressure, or the longer a rock is exposed to metamorphism, the greater the change will be. This is called a metamorphic grade. A low-grade rock has experienced less change than a high-grade rock.

KEY IDEA

Metamorphic rocks do not melt — if they do then they will be classified as igneous rocks.

Rocks do not always need to be buried to great depths to experience metamorphism. Figure 7.33 shows how rocks can be changed by the high temperatures that result from contact with hot magma. The metamorphic rocks around the body of magma are baked by the heat escaping the cooling magma body.

FIGURE 7.33 The formation of metamorphic rock by contact with hot magma



Types of metamorphic rocks

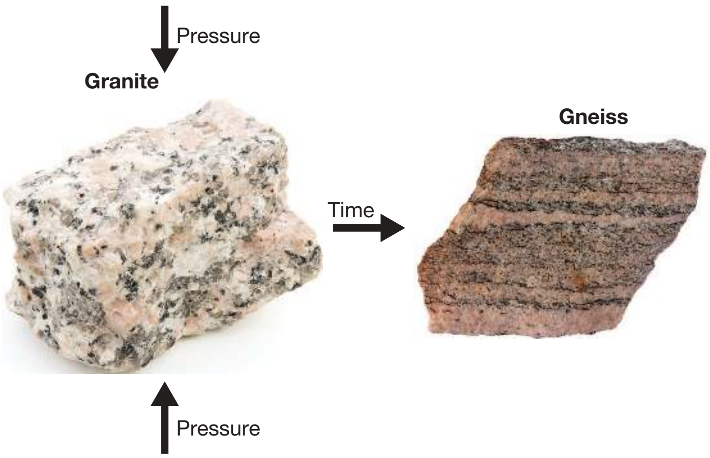
Shale is a common sedimentary rock made of tiny clay particles. It feels soft enough to scratch with your fingernail and is arranged in delicate layers that crumble easily. But when heat and pressure are applied to shale, the minerals change, and the rock hardens into **slate**, a low-grade metamorphic rock.

Slate still splits into thin layers like shale but is much harder and more durable. With more time and even greater heat and pressure, slate can morph into a high-grade rock called *schist* (figure 7.34).

Metamorphic rocks formed mainly by great pressure often show bands of light and dark colours. This happens because minerals rearrange into a preferred orientation, creating layers of similar minerals — a feature called **foliation**. An example of a foliated rock is **gneiss** (pronounced 'nice'). Gneiss will form when intense pressure transforms the igneous rock granite (figure 7.35).

FIGURE 7.34 When shale (left) is exposed to heat and pressure it becomes slate (centre). With further heat, pressure and time, slate can become schist (right). They do not look much different in photographs, but slate will be much harder than shale, and schist has larger mica that makes the rock sparkle.

FIGURE 7.35 When granite is exposed to high pressure it becomes a foliated gneiss.



Marble forms when limestone is put under heat and pressure. It contains the same calcite minerals as limestone, although they generally grow larger with metamorphism. If the limestone has minerals other than calcite in it, the marble will have a swirling colour effect.

FIGURE 7.36 A marble quarry in Italy. Marble forms from the metamorphism of limestone.

Common examples of the formation of metamorphic rocks are summarised in table 7.8.

TABLE 7.8 How some common metamorphic rocks are formed

'Parent' rock	Condition of metamorphism	Metamorphic rock
Shale (sedimentary)	Mainly low pressure/heat ⇒	Slate
Sandstone (sedimentary)	Mainly heat ⇒	Quartzite
Limestone (sedimentary)	Mainly heat ⇒	Marble
Granite (igneous)	Mainly high pressure ⇒	Gneiss

EXTENSION: Clues from metamorphic rocks

You cannot actually see metamorphism, because it takes place entirely underground. This makes metamorphic rocks the most mysterious of the three rock groups. However, the nature of metamorphic rocks above and below the ground can provide clues about the history of an area.

Think about why the presence of **quartzite** or marble high in a mountain range would suggest that the area was once below a shallow sea. The presence of slate might suggest that the area was once the floor of a still lake or deep ocean. These original rocks were either deeply buried, or exposed to magma, or pushed and pulled during a mountain-building event to transform them into new rock.

7.6.3 Useful metamorphic rocks

The unique hardness and ability for it to be split into thin layers has historically made slate useful as roofing or flooring material. Quartzite is also very hard and has been used for building materials.

Marble's softness, colour range and beautiful appearance make it suitable for sculpting. It is also used in building, for tiles, columns, walls and floors (inside and outside). It is usually highly polished. Ground-up marble can also be used in toothpaste, pharmaceuticals, agriculture mixtures, cosmetics, paper, paint and aggregate for construction.

The sedimentary rocks from which marble and slate are formed cannot be used for many of these purposes as they are not as durable.

DISCUSSION

Some have argued that black coal is actually more of a metamorphic rock than a sedimentary rock. Discuss why this may be, and what you would call it.

INVESTIGATION 7.6

Rocks — the new generation

Aim

To examine and compare a selection of metamorphic rocks and their corresponding 'parent' rocks

Materials

- labelled samples of granite, gneiss, limestone, marble, sandstone, quartzite, shale and slate
- hand lens

Method

1. Try to sort the rocks into pairs of 'parent' rock and corresponding metamorphic rock. Use the descriptions and examples in this lesson if you have trouble pairing the rocks.
2. Examine each pair of rocks with a hand lens. Take particular note of grain or crystal size and banding.
3. If necessary, re-sort the rocks into different pairs.

Results

Complete the table provided by noting the similarities and differences between the 'parent' and metamorphic rock of each pair.

'Parent' rock	Metamorphic rock	Similarities	Differences	Main cause of metamorphism
Shale				
	Gneiss			
Sandstone				
	Marble			

Discussion

1. Why is the term 'parent' used to describe the original rock before metamorphosis?
2. Use the last column of your table to suggest whether the main cause of metamorphism was heat or pressure.
3. Is there a pattern to the rock's appearance that could help you determine that pressure was a main cause of metamorphism?
4. Suggest an idea or two about why or how the metamorphic layering and banding could form.

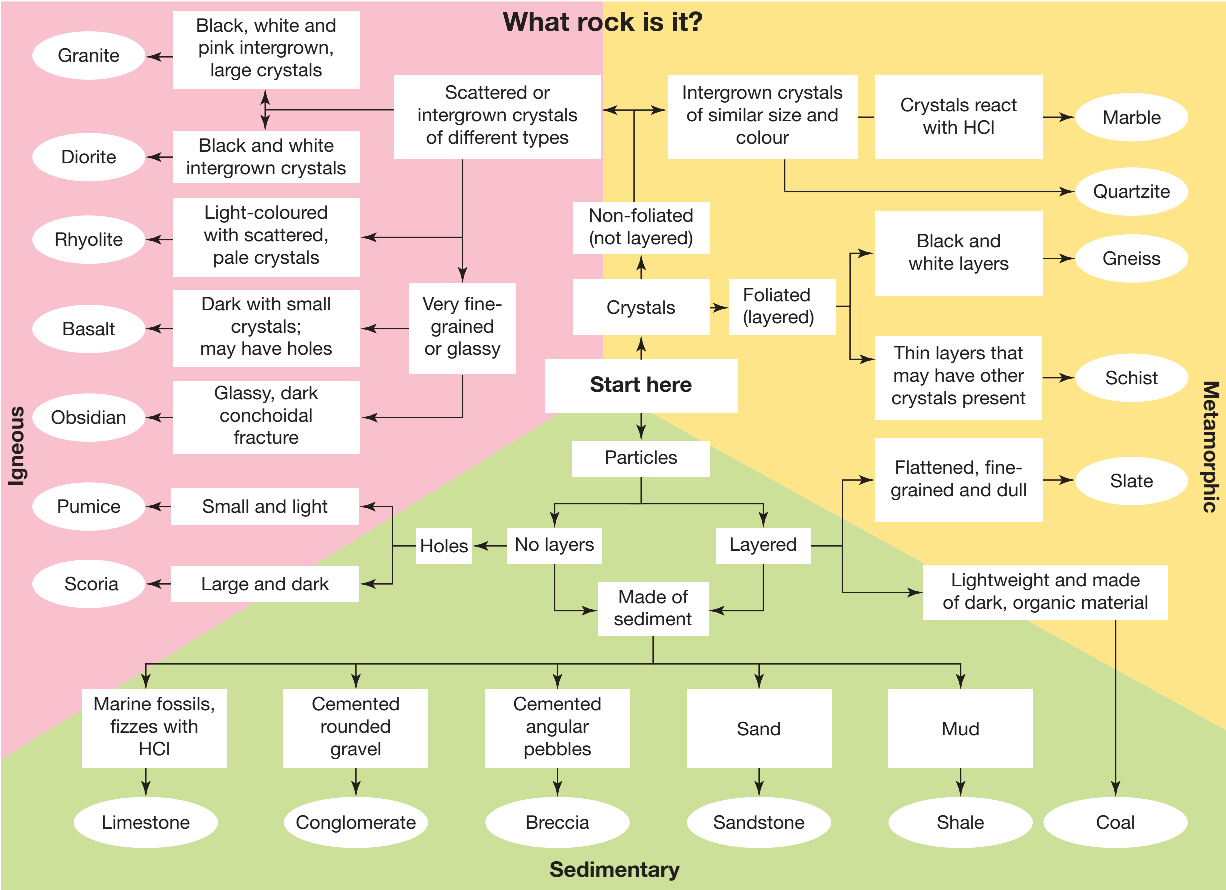
Conclusion

What can you conclude about metamorphic rocks and their 'parent' rocks?

7.6.4 Identifying major rock types

The key in figure 7.37 can be used to identify some of the more common rocks. Start in the middle and choose a path based on your observations. First, identify whether the rock consists mainly of crystals (that sparkle) or organic matter (that does not). A magnifier might help you.

FIGURE 7.37 A key for identifying major rock types



Note: Not all rock types are included in this key.

ACTIVITY: Rock hunt

Find a rock outside or in your neighbourhood and see if you can identify it!

7.6 Activities

learnon

7.6 Quick quiz on	7.6 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3	4, 6	5, 7, 8

Remember and understand

1. MC What causes rocks to become metamorphic?
   A. They cool and harden from molten rock.
   B. They are broken down by wind and water over time.
   C. They are subjected to heat and pressure, which changes their structure.
   D. They dissolve in water and reform as new minerals.

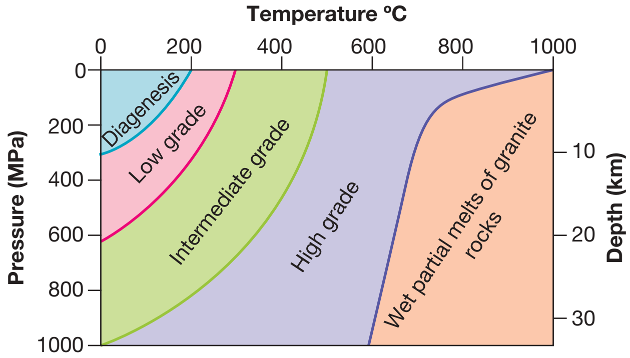
2. MC Why is limestone called the 'parent' rock of marble?
   A. Limestone melts and turns into marble over time.
   B. Marble forms when limestone undergoes heat and pressure, changing its structure.
   C. Limestone and marble are the same rock with different names.
   D. Marble is created by compacting layers of limestone underwater.
3. **Describe** the environments where you would expect to find metamorphic rocks forming.

Apply and analyse

4. Metamorphic rocks are generally formed deep below the surface of Earth. However, they are often found above the ground — even high in mountain ranges. **Explain** how this can be so.
5. If a rock gets so hot that it melts completely, it does not become a metamorphic rock. **Explain** why.

Evaluate and create

6. SI Consider the provided figure, which shows the different grades of metamorphism in rocks. As the pressure and/or temperature changes, the minerals in the rock become unstable, break down and form new minerals. The growth of particular minerals indicates that a grade boundary on this graph has been crossed.



   a. What are the relationships between temperature, pressure, depth and metamorphic grade?
   b. What is the temperature range for a low-grade rock found at a depth of 10 km?
   c. What are geologists using to recognise the difference between low- and high-grade metamorphic rocks?
   d. **Suggest** a definition for *diagenesis* and find out how it differs from lithification.
7. SI A geologist finds an outcrop of marble near an outcrop of granite. Knowing how both granite and marble form, answer the following questions.
   a. **Suggest** an idea that explains this relationship.
   b. **Explain** how you could test your idea.
8. **Construct** a design for a 'buildings trail' in your city or town to locate buildings made of different kinds of rock. **List** the locations of the buildings and the types of rock used in constructing them.

Answers and sample responses are available in your digital formats.

LESSON 7.7 The rock cycle

LEARNING INTENTION

In this lesson you will:
- describe the processes of the rock cycle
- explain how rocks transform over time
- interpret geologic history using evidence from rocks and fossils.

7.7.1 The processes within the rock cycle

The **rock cycle** (figure 7.38) shows how rocks can transform from one type to another. Processes such as weathering, erosion, deposition, uplift, heat, pressure, melting and crystallisation drive these transformations. Unlike other cycles, the rock cycle does not follow a set order, and it usually takes a very long time for rocks to change.

Some rocks have remained unchanged for millions of years and may stay the same for millions more. Others, especially in areas around tectonic plate boundaries, change more quickly — though still very slowly by human standards. These transformations happen due to Earth's internal heat, tectonic processes, as well as the effects of water, wind, gravity and even human activity. These processes occur at different speeds, scales and time periods. See table 7.9 for descriptions.

FIGURE 7.38 The processes of melting, metamorphism by increased heat and pressure, as well as weathering and erosion over time, will change rocks from one type to another. This is called the rock cycle.

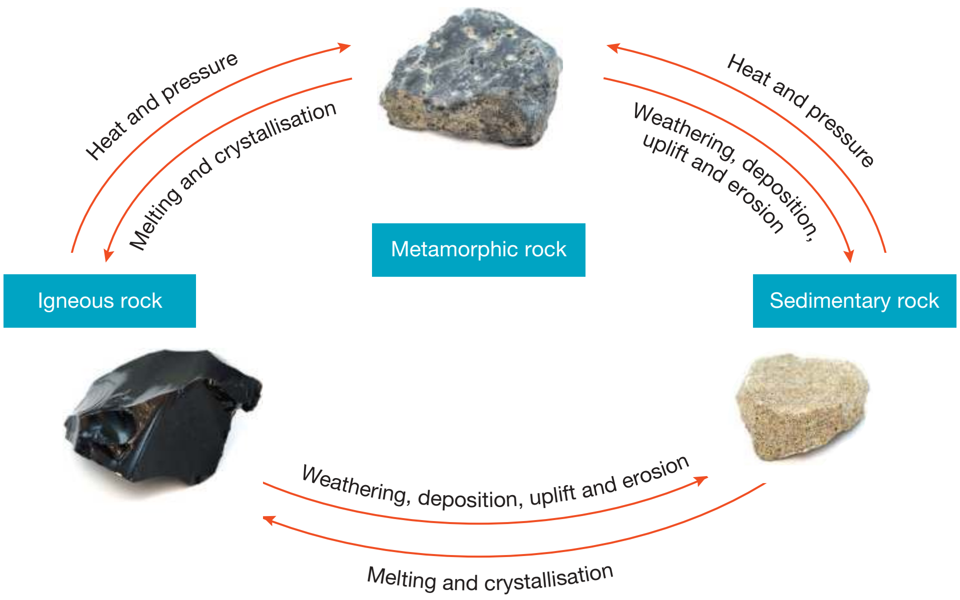


TABLE 7.9 Processes within the rock cycle

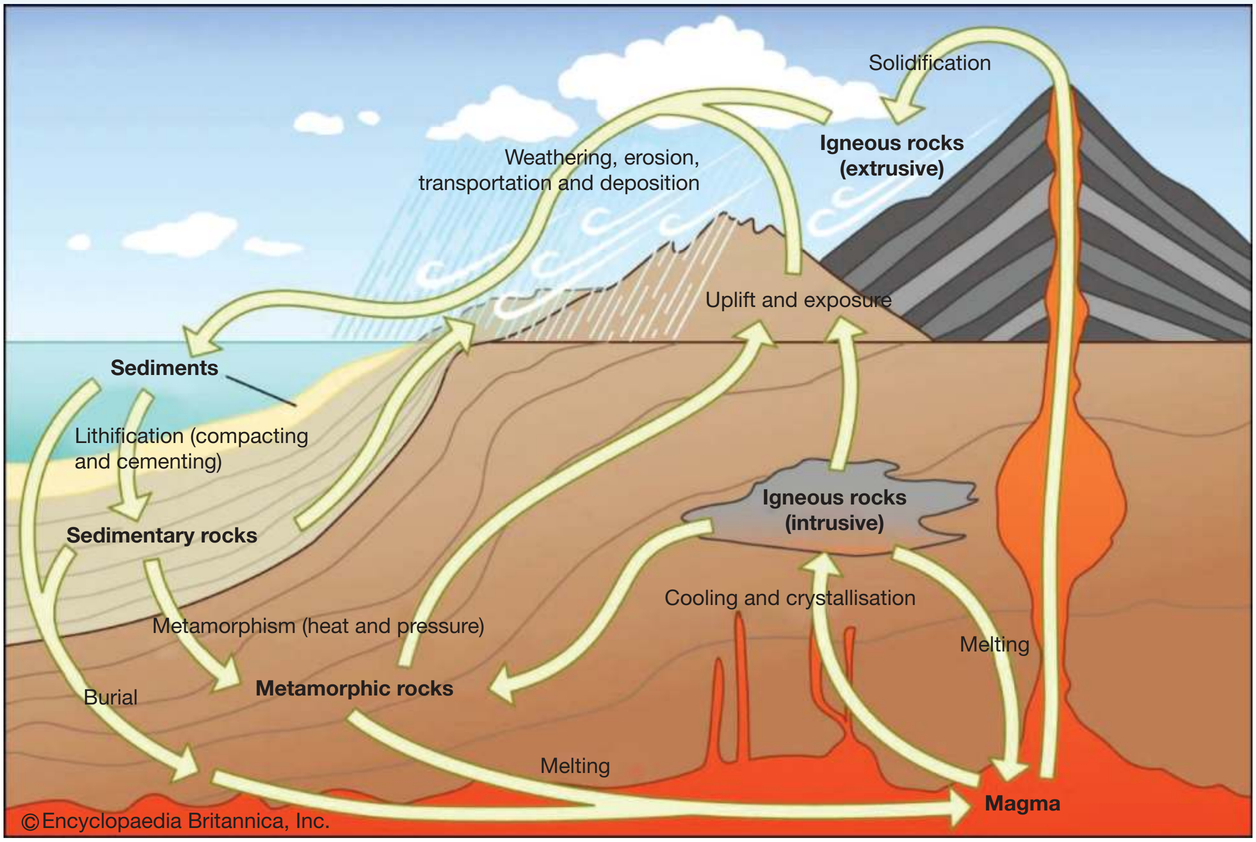
Process	Description	Rock type formed	Timescale (approx.)
Heat and pressure	Earth's internal heat and pressure can transform a rock into a metamorphic rock or melt it completely and form igneous rock. Meteorite impact can cause metamorphism at very high pressure and low temperature.	Igneous Metamorphic	Hundreds of thousands to millions of years (or minutes for a meteorite impact)
Weathering	The action of weather conditions on the breakdown of rocks; it is influenced by precipitation, temperature, topography and vegetation cover.	Sedimentary	Days to millions of years
Erosion	The wearing down of rock due to water, wind, ice or gravity, atmospheric and ocean circulation patterns, and regional topography.	Sedimentary	Days to millions of years
Uplift	Weathering and erosion of tectonically uplifted, newly exposed rock creates sediments.	Sedimentary	Thousands to millions of years
Transportation and deposition	The movement of particles to a resting place (e.g. river deposits, delta, volcanic ash eruption)	Sedimentary Volcanic	Days to thousands of years

(continued)

TABLE 7.9 Processes within the rock cycle *(continued)*

Process	Description	Rock type formed	Timescale (approx.)
Lithification	Compaction and cementing of sediments during burial, under low pressure conditions, to form rock	Sedimentary Volcanic	Thousands to millions of years
Melting	The melting of a rock, such as in a subduction zone or at great depth	Igneous	Millions of years
Crystallisation	The solidification of magma as it cools at the surface (extrusive rock) and below the ground (intrusive rock)	Igneous	Days to months (extrusive rock) to thousands of years (intrusive rock)
Human activity	Factors such as urbanisation, deforestation, agriculture and mining can result in increased erosion.	Sedimentary	<300 years

FIGURE 7.39 Typical settings and processes that operate in the rock cycle



DISCUSSION

A tadpole grows into a frog, female frogs lay eggs and eventually more tadpoles emerge from the eggs. That is a life cycle.

Some of the changes in rocks can be described as cycles too. Weathered rock is moved by erosion and the particles form sediments, which can be cemented together to form sedimentary rocks, which in turn may eventually change into metamorphic rocks. Once those rocks are exposed at the surface the weathering starts all over again. A complete cycle normally takes millions of years, but sometimes never takes place at all. Why?

7.7.2 If rocks could talk

If rocks could talk, they would reveal incredible stories about Earth's history! They would share tales of:
- prehistoric creatures whose fossils are preserved within them
- explosive volcanoes, powerful earthquakes and floods that carried them away
- what it is like inside Earth.

Even though rocks cannot talk, geologists 'read' them like a book to uncover the past. They use clues in the rocks to answer questions such as:
- How has Earth's climate changed over millions of years?
- When did the Himalayas form?
- What were the first signs of life?
- What caused the extinction of the dinosaurs?

These clues come from the appearance of rocks, the minerals they contain, their layers and fossils preserved within them.

7.7.3 Geologic history

Over millions of years, Earth changes dramatically. Rivers change course, mountains rise, seas dry up and the climate shifts. These changes are recorded in layers of sediment that build up over time. Each layer represents a snapshot of history, with the oldest layers at the bottom and the youngest at the top.

Sudden events, such as volcanic eruptions or landslides, also leave traces in these layers. Over time, forces beneath Earth's surface can tilt, bend or break these layers, creating a record of these movements. Geologists study sedimentary rocks to piece together the story of Earth's past, using the concept of **relative age** to figure out the order of events.

KEY IDEA

Geologists use these basic rules to understand the order of events.
- Older layers are at the bottom and younger layers are on top.
- Sedimentary layers are originally horizontal. If they are bent or broken, it means this happened *after* they were deposited.
- Erosion and weathering can remove layers, creating gaps in the record. These gaps are like missing pages in a book but mark the start of new layers being deposited.

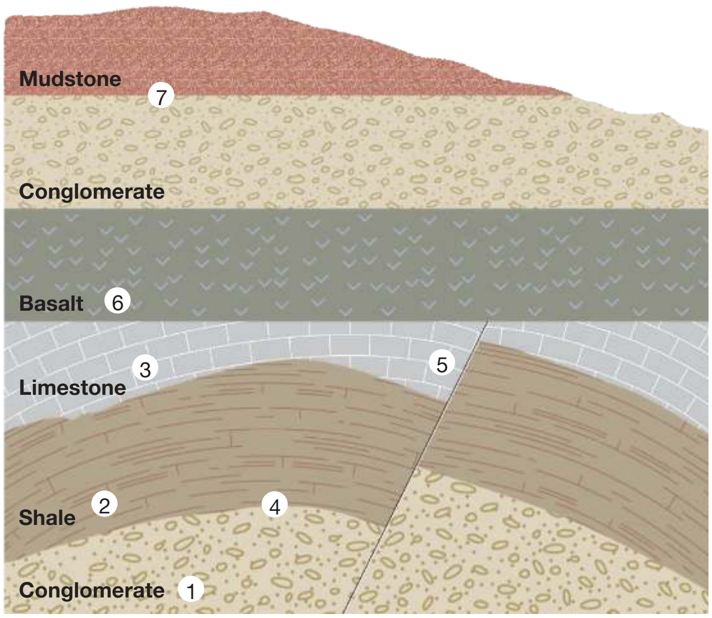
Relative dating is not just for sedimentary rocks; it can also be used to study some igneous and metamorphic rocks.

DISCUSSION

The present is a key to the past. As a class, or in a small group, discuss how much time you think it took to complete the sequence of events in figure 7.40. What observations of the modern world can we use to judge how quickly geologic events occur?

FIGURE 7.40 Illustrated side-view of a portion of the crust. It highlights the relationships of rock layers relative to one another, which can be used to propose a geologic history.

7 These layers were deposited last. They have started to weather and erode.
6 A long period of weathering and erosion left the layer of limestone with a flat surface. When a volcano then erupted nearby, lava from the volcano cooled to form basalt on the flat surface.
5 A sudden event such as an earthquake has occurred to break the layers of rocks like this. This event took place after the lower layers were folded. A break like this is called a fault.
4 A slow event has caused the lower levels to buckle. This is called folding. Folding can occur when rock layers are under pressure from both sides.
3 The third event to occur was deposition of limestone. It tells us that there were probably marine organisms present in the area during this time.
2 This is the second layer deposited. Shale is a fine-grained rock that is deposited in a quiet environment — such as a swamp, lake or slow-flowing part of a river.
1 Conglomerate was deposited first in this rock sample. This layer was deposited by a glacier or an active environment — such as a very fast-flowing river.



SCIENCE INQUIRY: Different types of rocks and the rock cycle

Aim

Write a scientific report investigating the major properties of different types of rocks (igneous, sedimentary and metamorphic) and how they fit into the rock cycle.

What to include in the report

1. Clearly describe the methods used to observe and test the properties of each rock type.
2. Include appropriate scientific conventions such as labelled diagrams, data tables and accurate terminology.
3. Discuss how the properties of the rocks relate to their formation processes and placement within the rock cycle.
4. Identify any assumptions made during the investigation and explain how they might have influenced your results.
5. Evaluate possible sources of error in your observations or methods and suggest how these could be addressed in future studies.

Ensure your report is structured with an introduction, method, results, discussion and conclusion.

Evidence-based arguments can be constructed to support conclusions or evaluate claims, including consideration of ethical issues and protocols associated with using or citing secondary data or information (VC2S8I07)

7.7 Activities

learnon

7.7 Quick quiz on	7.7 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 4, 5, 6, 9	3, 8, 10, 12	7, 11, 13

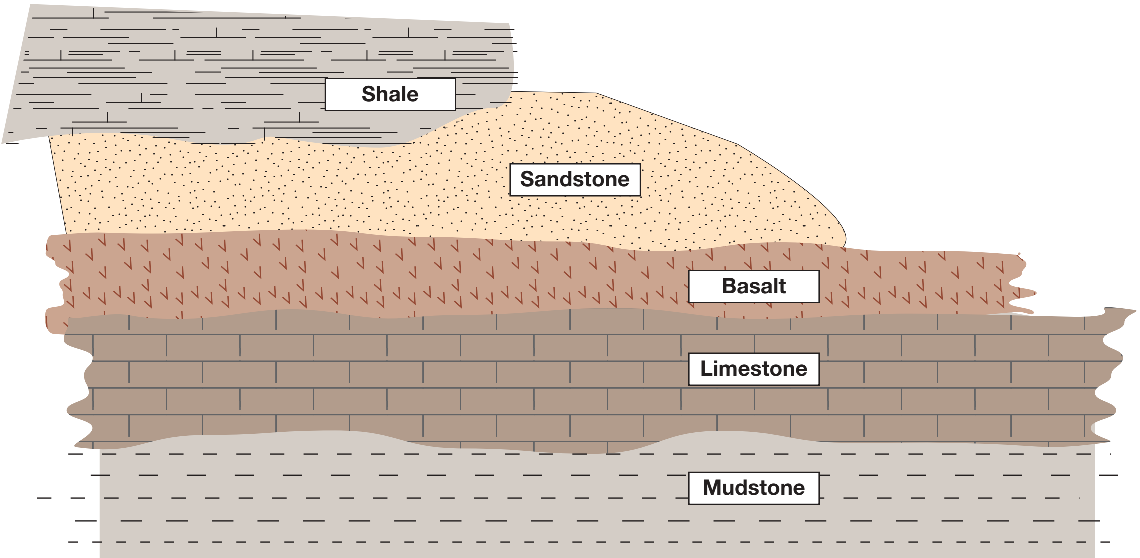
Remember and understand

1. Briefly **describe** the three basic rock types.
2. **Name** the process that turns sediment into a sedimentary rock.
3. **Identify** if the following statements are true or false.
   a. The rock cycle follows a strict, predictable order.
   b. Metamorphic rocks can form from any other type of rock.
   c. Weathering and erosion only happens at plate boundaries.
4. When magma cools and solidifies underground to form an intrusive igneous rock, this is called ___.
5. **Identify** what the relative age of a rock indicates.

Apply and analyse

6. **Explain** why some layers of sedimentary rock are tilted, even though the sediments that formed them were originally laid in horizontal beds.
7. **Explain** why geologists classify rocks.
8. **Identify** the progression of rock types if the steps in the rock cycle are as follows:
   melting and cooling → erosion and deposition → burial with increased temperature and pressure

Use the following figure to answer questions 9–11.



9. a. A road cutting reveals the layers of rock shown in the figure. Which of the rocks in the cutting is:
      i. the oldest rock
      ii. the youngest rock
      iii. evidence of volcanic activity?
   b. **Explain** why some layers in the figure are thicker than others.

10. In which rocks in the figure would you most likely find the fossil of:
   a. a seashell
   b. the leaf of a fern usually found in swamps?
11. If a fault cuts and displaces the mudstone, limestone and basalt layers in the figure:
   a. **identify** the relative age of the basalt and the fault
   b. **identify** the relative age of the sandstone and the fault.

Evaluate and create

12. **Discuss** why the rock cycle is important.
13. **Explain** how geologists know that processes in the rock cycle could take millions of years.

Answers and sample responses are available in your digital formats.

LESSON 7.8 Rock knowledge

LEARNING INTENTION

In this lesson you will describe how development of Stone Age tools required knowledge of rock types and how Aboriginal and Torres Strait Islander Peoples created tools for many specific purposes using their knowledge of different rock types.

7.8.1 Stone Age tools

SCIENCE AS A HUMAN ENDEAVOUR: Rocks as specialised tools

Rock technology began about two million years ago when early humans started using rocks to make simple chopping tools. This was the beginning of the period known as the **Stone Age**. For the great civilisations of Asia, Europe and North Africa, the Stone Age ended around 3000 BC with the discovery of bronze, an **alloy** of copper and tin.

The most commonly used resource in the Stone Age was a fine-grained sedimentary rock called **flint**. When flint breaks, it leaves a razor-sharp edge, so it was ideal for making sharp tools such as knives, axes and spearheads.

FIGURE 7.41 The use of chipping one rock with another to make the desired shape

FIGURE 7.42 Flint arrowheads were attached to wooden shafts with twine or animal sinews.

Small tools were made by striking tool stones such as flint or the glass-like igneous rock obsidian with harder stones (hammerstones) such as quartzite, a metamorphic rock. To remove large flakes from the tool stone, a sharp blow was delivered by the harder rock. If the tool stone was struck correctly, a flake sheared from it.

This process is called **percussion flaking**. The toolmaker continued to remove flakes from the stone until the desired shape was obtained. The flakes were then used to make tools such as knife blades, scrapers and engravers.

Larger items such as axeheads and spearheads were made with a combination of techniques, such as percussion flaking, grinding stones against each other and chiselling against the edge of a stone with tools made of bone or wood.

Indigenous ingenuity

Aboriginal and Torres Strait Islander Peoples were using Stone Age tools when Europeans began to colonise Australia in 1788. They were highly skilled at working with stone, being the first people to use ground edges on cutting tools and grinding stones to process edible seeds.

Their stone axes and other sharp tools were used to cut wood, shape canoes, chop plants for food, skin animals and make other tools out of stone or wood. The sharpened stones were often attached to wooden handles with twine from trees, resin from plants or with animal sinews.

FIGURE 7.43 Hand axes made and used by the Ngadjon-Jii Peoples of the tropical rainforests of northern Queensland

Grinding stones (figure 7.44) are slabs of stone used with a smaller, harder top stone to grind grains and seeds such as wheat, as well as corn, berries, roots, insects and many other things to prepare food for cooking. Leaves and bark were sometimes ground to make medicines. Aboriginal and Torres Strait Islander Peoples also used grinding stones to grind various types of soil and rock such as ochre to make the powders used to paint shields and other wooden implements with distinct markings specific to the nation group.

The tools and the type of stone used to make them varied from group to group, depending on the location. Aboriginal and Torres Strait Islander Peoples were skilled at making good use of the available resources. Apart from grinding stones, axes and other cutting tools, they made items such as bowls, cups and food graters out of stone.

FIGURE 7.44 A grinding stone made from sandstone. The top stone is a hard, smooth river pebble.

FIGURE 7.45 A food grater made from stone by the Ngadjon-Jii Peoples of northern Queensland

TABLE 7.10 Rock uses and their functional properties

Tool	Rock type	Rock properties
Ground-edge axe head	Volcanic rocks (e.g. diorite, basalt), slate	Durable and hard; can be shaped and take a sharpened edge
Stone knives and spear points	Slivers of quartzite, silcrete, obsidian	Hard with sharp edges; can be worked to an elongated shape
Hand axes and choppers	Volcanic rocks, silcrete	Hard with sharp edges; durable
Cutting tools and flakes	Quartzite, silcrete, obsidian	Durable with sharp edges; fits in hand
Anvil	Quartzite	Resistant; forms flat blocks 30–50 cm wide
Hammerstone	River pebbles of quartz or quartzite	Dense, round and hard
Grinding stone	Sandstone, basalt, quartzite (lower stone) River pebble (top stone)	Rough/abrasive; slab-forming (15–70 cm across) (lower stone) Dense, round and smooth; fits in hand (top stone)
Sharpening stone	Sandstone	Rough; forms broad, flat horizontal surfaces
Paint	Ochre (weathered rock containing iron oxide)	Has a range of colours; can be mixed with fat
Fuel	Coal	Burns slowly and retains heat; light to carry
Sacred stones	River pebbles	Waterworn and naturally shaped
Magic stones	Quartz crystals and unusually coloured or shaped stones	Attractive and unusual

1. How did Aboriginal and Torres Strait Islander Peoples adapt their use of rocks to meet their needs and make tools specific to their environment?
2. Why was flint such an important resource during the Stone Age? What properties made it useful for tools?
3. How did cultural knowledge and resource availability influence the tools and techniques used by Aboriginal and Torres Strait Islander Peoples compared to other ancient civilisations?
4. What role do properties such as hardness, durability and abrasiveness play in the selection of rocks for specific tools?
5. How does the process of percussion flaking demonstrate the application of scientific principles in toolmaking?
6. What can modern scientists learn from the resourcefulness and sustainable practices of Aboriginal and Torres Strait Islander Peoples when using natural resources?
7. How has the study of ancient tools and rock technology advanced our understanding of early human civilisations?

Multidisciplinary endeavours to advance scientific knowledge make use of people's different perspectives and worldviews (VC2S8H02)

7.8.2 Aboriginal and Torres Strait Islander Peoples' quarries

Aboriginal and Torres Strait Islander Peoples used quarries to extract stone for making tools, trading and other cultural purposes. These quarries ranged in size from single boulders to large areas such as riverbeds or gibber plains (stony deserts). Stones from quarries were highly valued, and some tools, such as axes, were traded as far as 800 km away.

Types of rock quarried included basalt, obsidian and quartzite. Soils with ochre, used for art and ceremonies, were also mined. High-quality stone meant bigger quarrying operations and wider trade.

Quarry use and trade

- Some groups of Aboriginal and Torres Strait Islander Peoples would gather near quarries to trade stone and ochre and hold cultural ceremonies.
- Ownership of quarries rested with local custodians, who controlled access to their resources and gave permission for quarrying on their land.
- People with special skills were responsible for extracting stone efficiently.

Quarrying methods

Aboriginal and Torres Strait Islander Peoples used two main quarrying methods.

1. Breaking off stone: using a hammerstone to hit an outcrop and break off pieces
2. Digging for buried stone: excavating around and under outcrops to find unweathered stone

Some quarries, such as a flint mine in South Australia, extended underground — up to 75 m deep and 300 m long.

Tool Preparation

Quarry workers trimmed stone into convenient shapes, called *blanks*, for making tools such as axes. Final shaping and grinding often happened elsewhere. Heavy tools such as hammerstones and grinding stones were usually left at the quarry.

CASE STUDY: The Wilgie Mia red ochre mine

Wilgie Mia, or Thuwarri Thaa (the place of red ochre), on Wajarri Country in Western Australia is the largest and deepest ochre mine in Australia. Believed to be 27 000 years old, it is thought to be the oldest continually worked mine site in human history. The ochre is very high quality and was traded around Australia.

Initiated Wajarri Yamatji men mined the ochre using heavy stone hammers and fire-hardened wooden wedges to pry away rock, which was then broken up to separate the ochre. Pole scaffolding and wooden platforms were used so they could simultaneously mine at different heights, increasing output.

FIGURE 7.46 Mining for red ochre at Wilgie Mia on Wajarri Country in Western Australia

CASE STUDY: Mount William Stone Hatchet Quarry

During the late Holocene (about the last 5000 years), as woodlands expanded in eastern Australia, ground-edged stone hatchets became essential tools for Aboriginal and Torres Strait Islander Peoples. These versatile tools were used for food-gathering, canoe-building and crafting weapons. The Mount William Stone Hatchet Quarry on Wurundjeri Country in Central Victoria was a key source of high-quality stone, traded across southeast Australia.

The quarry features 268 pits and shafts, some several metres deep, and 34 production areas, where stone was shaped into hatchet head blanks. Large debris mounds show the scale of production and trade.

Explore the design of Aboriginal and Torres Strait Islander Peoples' stone hatchets. How did their shape and materials make them effective for daily life and trade?

FIGURE 7.47 The Mount William Stone Hatchet Quarry on Wurundjeri Country in central Victoria

7.8 Activities

learnon

7.8 Quick quiz on	7.8 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3	4, 5, 8	6, 7

Remember and understand

1. **List** one example of each of the following types of rock that were used in the Stone Age to make tools.
   a. Igneous
   b. Sedimentary
   c. Metamorphic
2. **Name** the alloy that replaced stone to make tools when the Stone Age ended.
3. **Explain** the role that animal sinews played in tool-making by Aboriginal and Torres Strait Islander Peoples.
4. **List** three different uses of grinding stones.

Apply and analyse

5. **List** the properties of flint that made it so useful during the Stone Age.
6. **Suggest** how the process of percussion flaking got its name.
7. **Discuss** some properties that you would look for when selecting a suitable top stone for a grinding stone.

Evaluate and create

8. Think about the range of tools and other devices made from rocks or other natural materials that Aboriginal and Torres Strait Islander Peoples used in their daily lives. Can you think of another tool? **Explain** how it would be used and what it would be used for.

Answers and sample responses are available in your digital formats.

LESSON 7.9 Fossils

LEARNING INTENTION

In this lesson you will:
- understand how fossils are formed
- examine how they help us to interpret Earth's geologic and living history.

7.9.1 It is all relative

Fossils provide a way of finding out how living things have changed over time. Evidence of the very oldest living things is buried within the deepest and oldest layers of rock. Scientists who study fossils are called **palaeontologists**.

Since it is almost certain that a layer of sedimentary rock is older than the rocks above it and younger than those below, it can be assumed that the fossils in lower layers are older than those in the layers above. By comparing fossils found in rocks in different areas, including different continents, it is possible to compare the relative age of rocks throughout the world.

FIGURE 7.48 Fossils provide clues about life in the past. This is a fossil of an ancient fish.

7.9.2 How fossils form

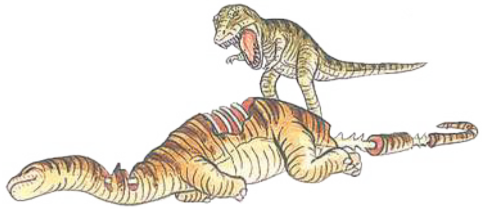
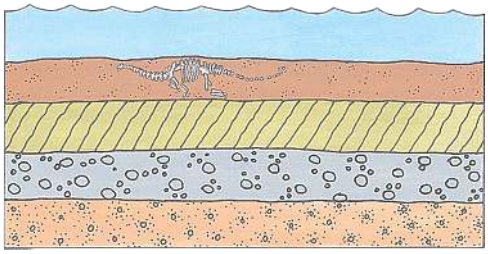
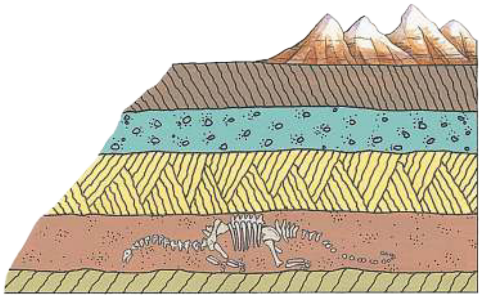
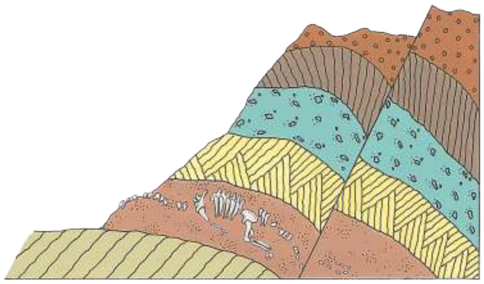
The remains of most animals and plants decay or are eaten by other organisms, leaving no trace behind. However, if the remains are buried in sediments before they disappear, they can be preserved, or fossilised. Fossils can form in several ways.

The hard parts of plants and animals are more likely to be preserved than the softer parts. Wood, shells, bones and teeth can be replaced or chemically changed by minerals dissolved in the water that seeps into them. Fossils are most commonly formed in this way (**permineralisation**) and are the same shape as the original remains but are made of different chemicals. Petrified wood, opalised fossils and fossil dinosaur bones are examples of fossils formed by permineralisation.

FIGURE 7.49 A selection of opalised fossils. These are opals that have formed within cavities in sand and clay left by the remains of living things, such as shells, teeth and bones, creating incredible fossil replicas.

Animal bones and shells can be preserved in sediments or rock for many years without changing. The types of bones, shells and other remains found in the layers of sedimentary rock provide clues about the environment, behaviour and diets of ancient animals.

Dinosaurs preserved in rock

1. After the death of a dinosaur, its body would usually be eaten by meat-eating animals (**carnivores** or **scavengers**). Its bones would be crushed or weathered, leaving no remains. If, however, the remains of a dinosaur were buried in sediment, the bones could be preserved.	
2. If a dinosaur died near a muddy swamp, shallow lake or riverbed, its remains sank in the mud or were washed into a river in a flood. The bones were quickly buried in sediment.	
3. Over millions of years, more layers of sediment were deposited on top of the buried remains. Chemicals that dissolved in the water that seeped into the remains changed their colour and chemical composition. The shape, however, was preserved. The sediments were gradually transformed into sedimentary rock.	
4. The layers of rock containing the fossilised remains were pushed upwards, bent and tilted by forces beneath Earth's surface. Weathering and erosion by the wind, sea, rivers or glaciers might expose one or more of the bones or teeth. If the exposed fossils were discovered before being buried again, palaeontologists might be able to recover them.	

Whole bodies

Sometimes, fossils of whole organisms, including the soft parts, are preserved. Such fossils are rare and valuable. Insects that became trapped in the resin of ancient trees (the fossilised resin is called amber) have sometimes been wholly preserved (figure 7.50). Similarly, if the remains of animals or plants are frozen and buried in ice, they can be fully preserved.

Whole bodies of ancient woolly mammoths (including skin, hair and internal organs) have been found trapped in the ice of Siberia and Alaska (figure 7.51). Whole bodies and preserved skulls of animals can even reveal evidence of their last meal before death. Scientists collect DNA from these remains and compare the DNA sequences to those of modern elephants. Could we one day clone a woolly mammoth?

FIGURE 7.50 These insects were trapped in the resin of a tree millions of years ago.

FIGURE 7.51 Whole bodies of ancient woolly mammoths have been discovered in the ice of Siberia and Alaska.

Making an impression

The remains of animals or plants sometimes leave a dark impression, or imprint, in hardened sediments or newly formed rock (figure 7.52). The dark imprint is carbon, a reminder that the imprint came from a once-living thing.

It is also possible for remains trapped in rock to dissolve and be broken down; this leaves behind an empty space in the shape of the fossil. The depression is called a **mould**. If the mould is filled with minerals over time, it forms a **cast** (figure 7.53).

FIGURE 7.52 The imprint of a leaf from an ancient fern left in stone

FIGURE 7.53 The coiled external shell of an ammonite has created a mould (left), which filled with minerals to create the cast (right).

Leaving just a trace

Some fossils only provide signs of the presence of animals, not the animal itself, and are called **trace fossils**. A trace fossil can be a footprint, trail or burrow. Footprints preserved in rock can provide clues about ancient animals, including dinosaurs, and how they lived. By studying the shape, size and depth of footprints, hypotheses can be made about the size and weight of extinct animals, as well as how they walked or ran.

DISCUSSION

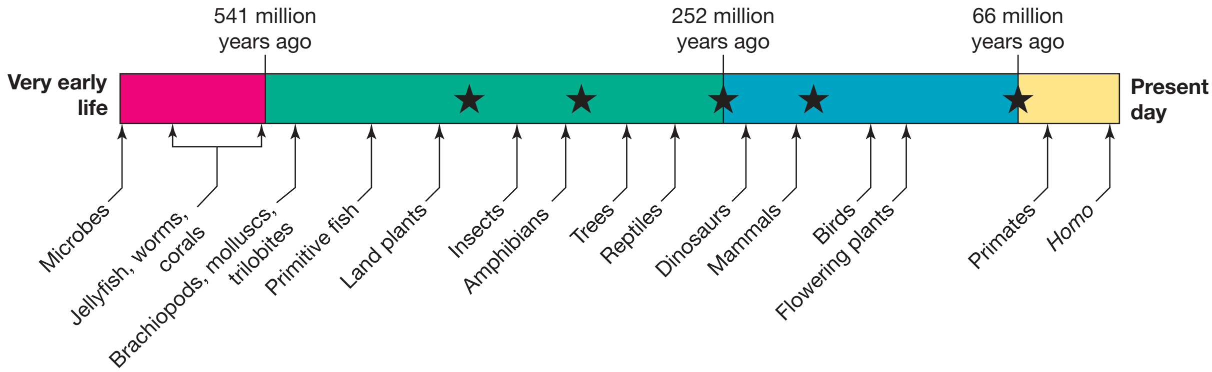
How complete is the fossil record? Having just learned about the various ways a fossil is formed, discuss what parts of organisms are most likely to be preserved in the fossil record, and what external conditions are required for those parts to be preserved.

7.9.3 Earth's living history

Despite the fossil record being incomplete, every fossil found helps to piece together the history of life on Earth. The oldest undisputed fossils are from rocks dated around 3.5 billion years ago in Western Australia. The fossils are photosynthetic single-celled organisms that formed features called *stromatolites*. They would have helped to introduce free oxygen into the atmosphere!

Fossils from the Ediacaran Period (636 to 541 million years ago) were the first multicellular forms, with soft bodies such as jellyfish or worms. Because the Ediacaran fauna did not have hard parts, they were not well preserved. However, after the Ediacaran Period, the rock record explodes with an abundance of fossils because organisms evolved with hard body parts such as claws, scales, shells and bones. Early life was dominated by marine organisms, but both animals and plants slowly grew in abundance and complexity on land.

FIGURE 7.54 A summary of Earth's living history for the last 600 million years, marking the first fossil records and major mass extinction events (stars)



The last 541 million years has seen five major **mass extinctions**, where large volumes of life disappear from the rock record. The most significant of these was around 252 million years ago, which saw the extinction of over 80 per cent of all species, including the trilobites (figure 7.55). Palaeontologists have placed most of the divisions of geologic time at points in the fossil record where there are major changes in the type of organisms observed in the rocks.

FIGURE 7.55 Trilobites were some of the first organisms with hard parts preserved in the fossil record, but are not found in any rocks younger than 252 million years.

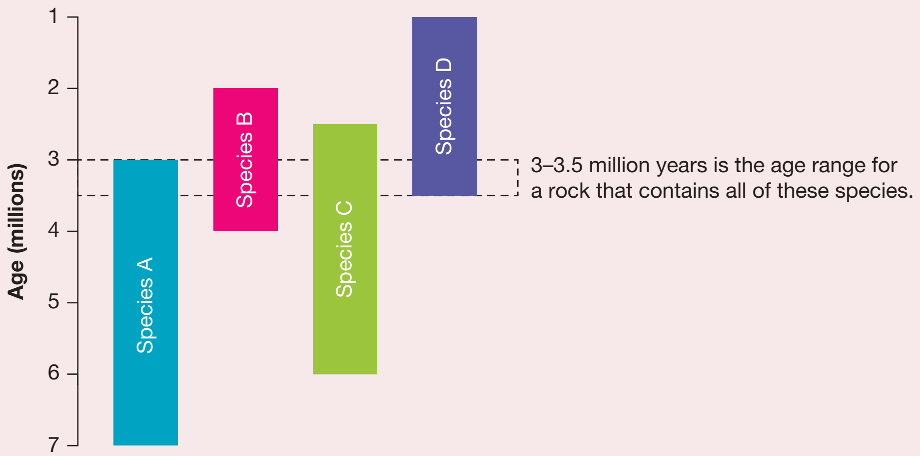
SCIENCE AS A HUMAN ENDEAVOUR: Fossils help to date rocks

Geologists use the fossil record to track fossil distribution over time and across Earth, helping to date and relate rocks over vast distances. Certain fossils, known as 'index species', are particularly useful because they are abundant, easily recognisable, short-lived in geologic time and widely distributed. Common index fossils include brachiopods, conodonts, dinoflagellate cysts, foraminifera, graptolites, spores and pollen, and trilobites.

Conodonts are extinct microfossils found in marine limestones of eastern Australia and China, indicating that these regions were located together about 450 million years ago!

If the rock being studied has several types of fossils in it, and time ranges can be assigned to those fossils, it might be possible to narrow the age range of the rock. First, the age range for each fossil is evaluated, then the overlap in age between fossils is determined. The overlap is the age, or time period, of the rock sample.

FIGURE 7.56 When a rock is found containing multiple fossils, the overlap of the fossil age ranges can narrow down the age of the rock.



1. How do index species help geologists date rocks and relate them across vast distances?
2. Why are fossils such as conodonts considered important for understanding Earth's geological history?
3. How does the discovery of overlapping fossil age ranges refine the process of dating rock samples?
4. How has the study of fossils, such as trilobites and foraminifera, contributed to our understanding of Earth's past environments and the movement of continents?
5. What challenges might scientists face when using fossils to date rocks, and how could they address these challenges?

Scientific knowledge, including models and theories, can change because of new evidence (VC2S8H01)

7.9.4 What happened to the dinosaurs?

Between about 66 and 252 million years ago, dinosaurs were the most successful animals on Earth. In fact, those years are known as 'the age of the dinosaurs'. Dinosaurs thrived and dominated the land while mammals lived in their shadow. Fossil evidence indicates that the last of the dinosaurs died about 66 million years ago.

Two of the inquiry skills that geologists and other scientists use are questioning and predicting. The question of how the dinosaurs died out has intrigued scientists for many years. In answering this question, scientists use scientific knowledge to make 'predictions' about what happened many millions of years ago.

The extinction of the dinosaurs remains a mystery. Scientists debate whether it happened suddenly or gradually and continue to search for clues. Several theories attempt to explain their disappearance.

FIGURE 7.57 Dinosaurs dominated the Earth from about 252 million years ago to 66 million years ago.

The asteroid theory

The most widely accepted theory to the dinosaur riddle is that an asteroid collided with Earth around 66 million years ago.

The asteroid's impact threw billions of tonnes of dust into the air, blocking out sunlight and plunging Earth into darkness for two or three years.

- Plants stopped growing but their seeds remained intact.
- The temperature dropped.
- The large plant-eating dinosaurs would have died quickly of starvation.
- The meat-eating dinosaurs would probably have died next, having lost their main food supply but surviving for a while by eating smaller animals.
- Many smaller animals would have survived by eating seeds, nuts and rotting plants.

As the debris began to settle and sunlight filtered through the thinning dust clouds, the surviving plants and animals began to thrive. The surviving mammals were no longer competing with dinosaurs for food. It was the beginning of the age of mammals.

FIGURE 7.58 A colliding asteroid could have created enormous dust clouds that blocked out sunlight for two or three years.

The volcano theory

Large volcanic eruptions could have spewed ash and gases into the atmosphere, cooling the climate by blocking sunlight. Evidence comes from smaller modern eruptions such as Mount Pinatubo in 1991, which caused a global temperature drop of 0.2 °C. Massive ancient eruptions, such as those in Siberia 252 million years ago, are linked to earlier extinctions and could have caused similar effects during the dinosaurs' time.

FIGURE 7.59 Huge volcanic eruptions could have caused a global cooling.

The cooling climate theory

The gradual cooling of Earth's climate due to changes in the Sun's activity or Earth's orbit around the Sun could have caused the extinction of the dinosaurs. Dinosaurs, with no fur or feathers, had less protection from cold weather than mammals and birds. The larger dinosaurs would have found it very difficult to shelter from the cold conditions. Many smaller animals could burrow below the ground, or shelter in the hollow trunks of trees or in caves. Many mammals and birds would have been able to migrate to warmer regions closer to the equator.

FIGURE 7.60 Could global climate change have killed the dinosaurs?

The emerging plants theory

During the Cretaceous period (145 million to 66 million years ago), new types of plants began to appear. Flowering plants evolved, competing with the more primitive plants such as ferns for nutrients, water and sunlight. The plant-eating dinosaurs did not eat flowering plants. According to this theory, as their traditional food supply became more scarce, the plant-eating dinosaurs could not survive, and the meat-eating dinosaurs that preyed on them starved as well.

FIGURE 7.61 The evolution of flowering plants may have wiped out much of the plant-eating dinosaurs' main food source.

The declining oxygen theory

During the 'age of the dinosaurs' the amount of oxygen in the atmosphere was higher than it is today — 10 to 14 per cent more. This meant that despite the dinosaurs having large bodies and muscles, they could get away with having small lungs.

Around 95 million years ago, the oxygen levels appear to drop rapidly to the 21 per cent we have today. It is possible that the decline in available oxygen was quicker than evolution could take place, and the dinosaur's biology did not cope with the lower levels of oxygen.

EXTENSION: Cold-blooded or warm-blooded?

Until recently, it was believed that dinosaurs were **ectothermic**. Ectothermic animals have body temperatures that depend on the temperature of their surroundings. As the surrounding temperature decreases, their body temperature decreases, and they become less active.

Mammals are **endothermic**. Endothermic animals are able to maintain a constant body temperature that is usually above that of their surroundings. They are able to remain warm and active in lower surrounding temperatures.

If dinosaurs were in fact ectothermic, a cooler climate would have made it more difficult for them to compete with other animals for food. However, many scientists now believe that dinosaurs may have been endothermic. The question of whether dinosaurs were cold-blooded or warm-blooded needs to be answered before the riddle of the dinosaurs can be solved.

CASE STUDY: Australian megafauna

The name *megafauna* means 'big animals' and is a general term used to describe a group of large land animals that appeared millions of years after the dinosaurs became extinct. The megafauna was at its largest and most widespread during the last 2.5 million years. In Australia, the megafauna was unique, including giant marsupials such as *Diprotodon*. *Diprotodon* is often referred to as a giant wombat with a nose like a koala. It was about the size of a two-tonne white rhinoceros.

Most of the Australian megafauna became extinct around 40 000 years ago. Scientists have been debating the causes of the extinction for decades. Some claim the animals could not have survived changes in climate, which would have changed landscapes from eucalypt woodlands to arid and sparsely vegetated grasslands. Others have suggested the animals were hunted to extinction by Australia's earliest immigrants, who had colonised most of the continent by 50 000 years ago. Perhaps it is a combination of the two.

FIGURE 7.62 A Diprotodon, the largest known marsupial to have ever lived. This giant herbivore roamed the open woodlands and grasslands of Pleistocene Australia over 46 000 years ago, serving as a distant relative to modern wombats and koalas.

7.9 Activities

learnon

7.9 Quick quiz on	7.9 Exercise

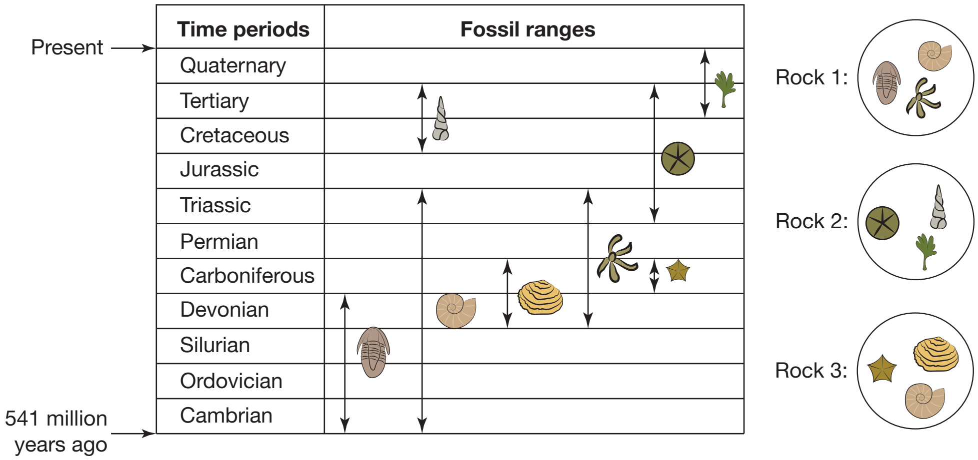
LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 4, 5, 10	6, 8, 11, 12	7, 9, 13

Remember and understand

1. MC What does a palaeontologist study?
   A. The movement of planets and stars
   B. Ancient life forms through fossils
   C. How earthquakes and volcanoes occur
   D. Different types of minerals found in rocks
2. MC What clues do fossils provide about life in the past?
   A. How stars and planets were formed
   B. The diets, habitats and behaviours of ancient organisms
   C. The weather patterns of the present day
   D. How plants grow in different environments today
3. **Explain** under what circumstances can whole living things be preserved as fossils.
4. **Identify** when a mass extinction took place that included the loss of most dinosaurs.
5. **Identify** the most widely accepted theory to explain the extinction of the dinosaurs.

Apply and analyse

6. Why would smaller animals be more likely to survive the effects of an asteroid impact or large volcanic eruption than larger animals?
7. **Describe** four ways an animal or plant can be fossilised.
8. SI **Explain** why the hard parts of plants and animals are more likely to be preserved than the softer parts.
9. SI Using the fossil age ranges (arrows) in the following figure, determine the time period of the three rocks shown.



10. **Discuss** how volcanic eruptions could affect life throughout the whole world.
11. SI The boundary that marks the extinction of the dinosaurs is known as the K-T boundary. When scientists sampled this boundary across the world, they found that it had a much higher concentration of iridium than normal. Iridium is rare on Earth's surface.
    a. Of all the theories presented, which theory does this finding best support?
    b. Are there any patterns to the iridium concentrations that would help convince you even further?

Evaluate and create

12. **Discuss** as many weaknesses as you can in each of the five theories about the dinosaur extinction presented.
13. Imagine what it would have been like 66 million years ago if an asteroid plunged into Earth. Write a story about the first 24 hours after the impact.

Answers and sample responses are available in your digital formats.

LESSON 7.10 Review

7.10 Success criteria

Tick the column to indicate that you have completed the lesson and how well you think you have understood it using the traffic light system.

(**Green:** I understand; **Yellow:** I can do it with help; **Red:** I do not understand)

Lesson	Success criteria	Green	Yellow	Red
7.2	I can define a mineral.			
	I can recognise that minerals have unique chemical and physical properties.			
	I can understand how they differ from rocks.			
7.3	I can explain mining processes.			
	I can analyse mining's economic contributions.			
	I can evaluate its environmental and societal impacts.			
7.4	I can describe the type of environments that igneous rocks form in and how they can be classified according to their composition and texture.			
7.5	I can describe how sedimentary rocks are formed and classified, and that they form in layers that record time and changes to Earth's surface.			
7.6	I can describe how some common types of metamorphic rocks form, and what clues they provide to past environments.			
7.7	I can describe the processes of the rock cycle.			
	I can explain how rocks transform over time.			
	I can interpret geologic history using evidence from rocks and fossils.			
7.8	I can describe how development of Stone Age tools required knowledge of rock types and how Aboriginal and Torres Strait Islander Peoples created tools for many specific purposes using their knowledge of different rock types.			
7.9	I can understand how fossils are formed and examine how they help us to interpret Earth's geologic and living history.			

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Post-test Topic 7 Post-test

eWorkbook Topic 7 eWorkbook

Digital document Key terms glossary

7.10 Activities

7.10 Review questions

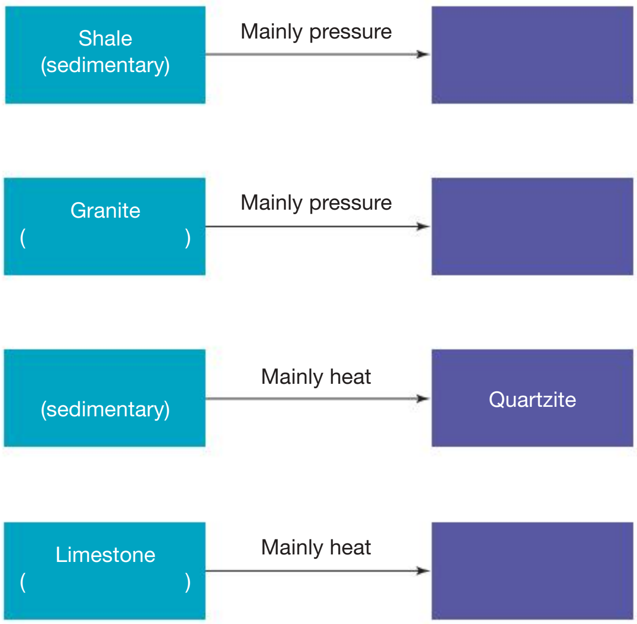
LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 4, 5, 6, 7, 9, 17, 21, 26, 27	8, 10, 11, 12, 13, 18, 19, 22, 28	14, 15, 16, 20, 23, 24, 25, 29, 30, 31, 32

Remember and understand

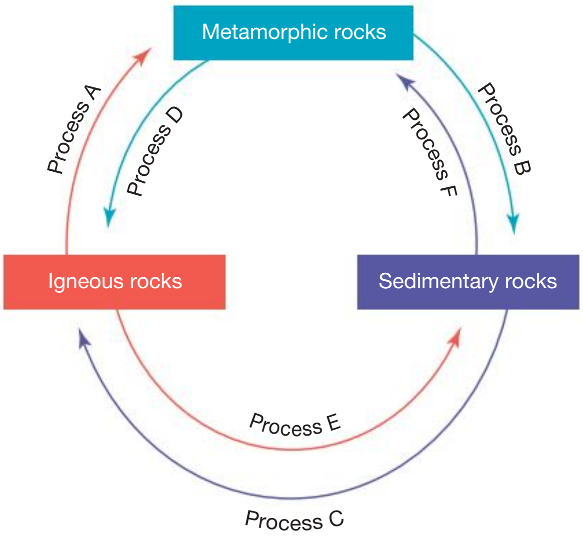
1. **List** the three requirements needed to call something a rock.
2. **Name** the three groups of rocks formed in Earth's lithosphere based on how they were created.
3. **Explain** how all igneous rocks are formed.
4. **List** three examples of extrusive igneous rocks.
5. What clues does the size of the mineral crystals in an igneous rock provide about how the rock was formed?
6. **Define** sediments.
7. **Explain** why some layers of sedimentary rocks are tilted or bent.
8. **Describe** three ways that sedimentary rocks can form.
9. **Explain** what a 'parent' rock is.
10. **Describe** two ways in which igneous and sedimentary rocks can be transformed into metamorphic rocks.
11. Complete the table to summarise what you know about igneous, sedimentary and metamorphic rocks.

Class of rock	How it is formed	Special features	Example	Uses
Igneous				
Sedimentary				
Metamorphic				

12. Complete the diagram of parent rocks and their rock type, on the left, and the common metamorphic rocks they form, on the right.



13. **Explain** why the mineral crystals in granite are larger than those in basalt.
14. **Discuss** how applying pressure changes the appearance of a rock.
15. The changes that lead to the formation of the three main groups of rocks can be drawn as a cycle, as shown in the figure.



Which of processes A–F involve:
a. weathering and erosion
b. heat and pressure
c. melting and crystallisation?
16. What characteristic of minerals do the following terms describe?
a. Lustre
b. Streak
c. Hardness
17. **Identify** what mineral property the Mohs scale provides an approximate measure of.
18. Which metamorphic rock is used by Aboriginal and Torres Strait Islander Peoples to make anvils? What properties make it useful?
19. Not all fossils are the actual remains of living things. **Name** two types of fossils that are not preserved remains.
20. Of the several ways a fossil can form, **state** which is the most common.

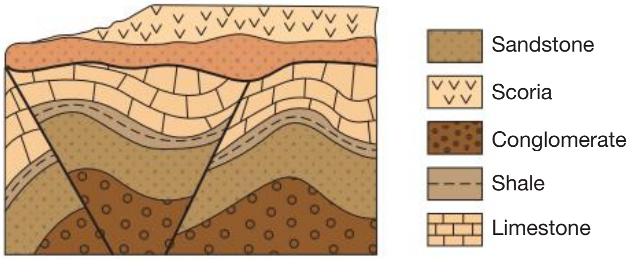
Apply and analyse

21. **Compare** the ways in which extrusive igneous rocks and intrusive rocks are formed.
22. SI **Suggest** a way of testing that a rock sample is limestone.
23. SI While studying sedimentary rocks in a railway cutting, a geologist discovers a layer of graded bedding, which features larger sized clasts at the bottom and the gradual decrease in size towards the top. **Suggest** how the graded bedding could have been made.
24. **Compare** the differences between basalt and rhyolite.
25. SI If you were given a sample of two different minerals:
a. how could you tell which one had the greater hardness
b. which one would you prefer to make a road out of?
26. The tools of Aboriginal and Torres Strait Islander Peoples are made by a process called percussion flaking.
a. **Describe** the process of percussion flaking.
b. Which property of the rock used to make the tool must be different from those of the stone from which the tool is formed?
27. **Name** the most common element in Earth's crust.
28. One factor that determines the way in which ore minerals are mined is their depth. **Compare** the mining processes used for ores located near the surface with those used for ores located deeper in Earth's crust.
29. The mining industry provides employment for many Australians. **List** some occupations that are involved in the mining industry. (*Hint*: Think about what happens before, during and after mining is undertaken.)

Evaluate and create

30. According to many geologists, parts of Antarctica are rich in mineral resources, similar to those found in Australia. Use a two-column table to **list** reasons these mineral resources should be mined and why they should not be mined.

31. This figure is a sketch of some rock layers and their relationships as seen from a cliff face of a canyon.
   a. What is the oldest rock?
   b. What is the youngest rock?
   c. What sort of event does the youngest rock suggest?
   d. Which feature represents a period of weathering and erosion?
   e. Is the period of weathering and erosion younger or older than faulting?
   f. SI Which layer in the diagram would most likely have fossils?
   g. Normally, old layers of rock are found below younger layers. Sometimes, however, younger layers are found beneath older layers. Can you **identify** a spot on the diagram where this has happened?



32. SI The photograph provided shows dinosaur footprints that have been preserved in rock at Gantheaume Point near Broome.
   a. What type of fossil is it?
   b. Why is it classified as a fossil even though it could be described as a dent in a rock?
   c. Have all dinosaur footprints been preserved? Why have these been preserved for hundreds of millions of years?
   d. What can be learned about the features of the dinosaur that left these footprints?
   e. What forms of evidence, apart from preserved footprints, can be used to gather knowledge about dinosaurs?

Answers and sample responses are available in your digital formats.

To test your understanding and knowledge of this topic, go to your learnON title at www.jacplus.com.au and complete the **post-test**.

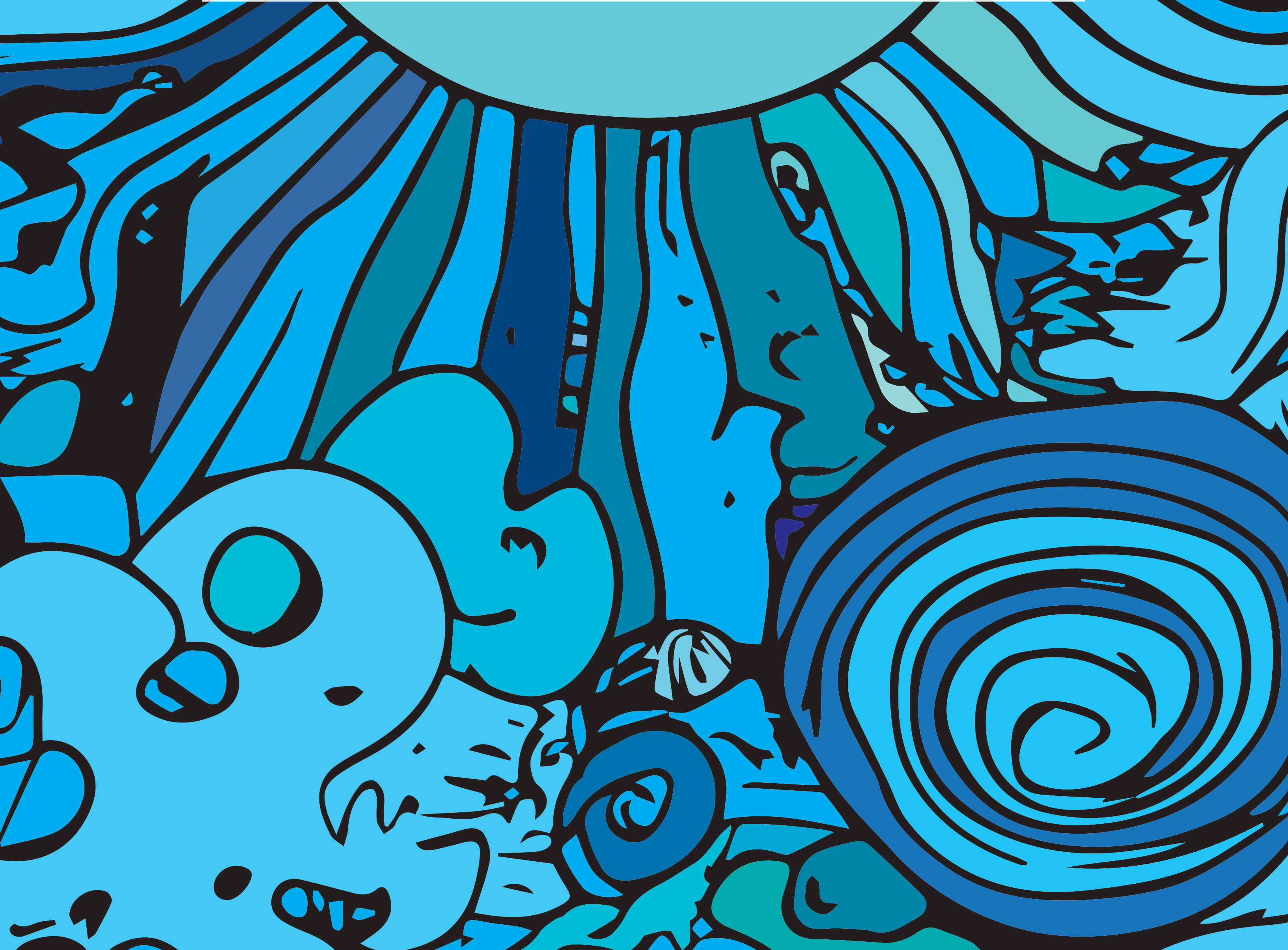
8 Energy

CONTENT DESCRIPTION

Energy exists in different forms, including thermal, chemical, gravitational and elastic, and may be classified as kinetic or potential; energy transfers (conduction, convection and radiation) and transformations occur in simply systems and can be analysed in terms of energy efficiency (VC2S8U15)

Source: Victorian Curriculum F–10 Version 2.0

LESSON SEQUENCE



LESSON 8.1 Overview

8.1.1 Introduction

A fireworks display is one of the most spectacular energy transformations; you can not only see it but also hear, feel and smell it. When fireworks are ignited, the chemical **potential energy** stored in the substances inside the fireworks is quickly transformed into different types of **kinetic energy** including movement, light energy, sound energy and thermal energy (more commonly called heat).

FIGURE 8.1 Fireworks are a spectacular display of energy transformation.

DISCUSSION

1. Which type of energy do you find in chocolate?
2. When you drop a tennis ball to the ground, why does it not return to its initial height?
3. How much electrical energy is wasted as heat by a filament light globe?
4. How do you get a swing started without someone to push you?
5. How do glow-in-the-dark stickers work?
6. Why do professional tennis players have racquets with different string tensions?

SCIENCE INQUIRY: Potential energy and kinetic energy

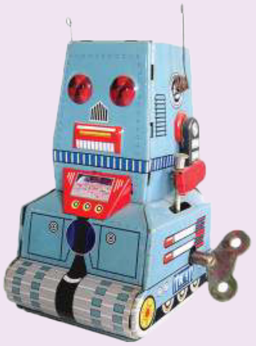
All substances and objects possess potential energy, however, it is impossible to detect the presence of potential energy until it transforms into a form of kinetic energy. For example, the energy stored in fireworks only becomes apparent when the fireworks explode, transferring the stored energy into movement, light, heat and sound. When a diver dives from a platform or diving board, the energy stored inside the diver (because of their height above the water) is transformed into kinetic energy and movement on the way down. The energy stored in the stretched string of an archery bow is transformed into the kinetic energy of the arrow when it is released.

FIGURE 8.2 Potential energy is everywhere. Examples include the gravitational potential energy that divers transform into kinetic energy when they dive off a diving board or platform, and elastic potential energy in bows.

1. Complete the table given. One example has been completed for you.

Object	What to do to release the stored energy	Potential energy is transformed into …
Torch battery	Switch it on	electrical energy and light energy
Chocolate		
Petrol		
Dynamite		
Olympic diver on platform		
Match		
Stretched elastic band		

2. Answer the following questions about the wind-up toy shown.
   a. Where is the energy stored when it is wound up?
   b. What do you have to do to allow the stored energy to be transformed into different forms?
   c. Name two forms of energy into which the potential energy is transformed.
   d. From where does the energy come that allows the user to wind up the toy?



Information and processed data can be analysed to show patterns, trends and relationships, and to identify anomalies (VC2S8I05)

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Pre-test	Topic 8 Pre-test
eWorkbooks	Topic 8 eWorkbook Student learning matrix
Practical investigation eLogbook	Topic 8 Practical investigation eLogbook
Digital document	Key terms glossary

LESSON 8.2 Different forms of energy

LEARNING INTENTION

In this lesson you will:
- describe the different forms that energy can take
- classify them as potential energy or kinetic energy.

8.2.1 What is energy?

Energy is a word that you sometimes use to describe how active you feel. However, in Science, we can define energy as the ability to make something happen.

Here are some key principles of energy:
- All things possess energy — even if they are not moving.
- Energy can **transfer** to another object (e.g. a cricket bat to a ball) and **transform** into a different form (e.g. electrical into sound).
- Energy can be stored.
- The SI unit of energy is the **joules (J)**.

SCIENCE AS A HUMAN ENDEAVOUR: Energy through the ages

Humans have always used energy. The earliest humans mainly used their own 'muscle power' to get jobs done, with the required energy coming from the food they ate. Fire was also important, being used for warmth, light and cooking. Fire was no doubt discovered through natural events such as lightning strikes, but methods to generate it were eventually discovered, mainly through utilising friction to produce heat. The methods used by Aboriginal and Torres Strait Islander Peoples to do this are discussed later, in section 8.4.4.

FIGURE 8.3 A replica of an ancient trireme. The sail and oars are clearly visible.

Solar energy was also used for warmth, and for drying food and clothes. In some parts of the world, people undertook annual migrations to follow prey animals as they moved to warmer climates during the winter months. With the domestication of animals such as horses, increased muscle power became available for farming and transport as well as warfare. As a result, people had more time to develop and spread new ideas rather than just hunting for prey and collecting firewood. This led to the development of specialised trades and an overall advance in civilisation. In one form or another, this occurred in many different geographical regions around the world.

The natural environment was also harnessed as an energy source. Waterwheels were one of the first inventions that used machines to replace the muscle power of animals and humans. One of their most well-known tasks was to grind wheat to make flour (for making bread). Other uses included:
- the operation of pumps to lift water
- driving sawmills
- operating bellows in forges
- powering heavy hammers.

However, because waterwheels required running water, their use was restricted to areas where this was available. Added to this was the problem that in some locations, the water sources were privately owned and therefore under the control of a few individuals.

Windmills were also an important invention for humans in our endeavours to harness energy from the environment. It is thought that the windmill was first used in the Middle East, its use then spreading to India, China and Europe. Mainly used for grinding grain and pumping water, windmills are still used in many parts of the world today. Australia has many remote locations where these are used to lift water to the surface from under the ground, thus permitting livestock to survive in otherwise waterless locations.

The other great need for harnessing energy was for transport. On water, muscle power in the form of rowing with oars was used, then supplemented and eventually replaced by wind energy captured via sails. Entire civilisations rose and fell based on their ability to trade, travel and conduct warfare over the seas adjoining their lands. In the Mediterranean, vessels called triremes were a common sight. These were propelled by three banks of rowers on each side of the boat, and a sail. The eventual progression to ships powered entirely by sails followed, allowing nations to explore and colonise new regions around the world.

The Industrial Revolution in the 1700s and the discoveries that followed completely changed the way humans harnessed and used energy. As a result of this:

- Traditional energy sources were able to be used in new ways. For example, heat energy was able to be obtained from fuels and used in a steam engine to produce movement (kinetic energy). This could then be used to replace windmills and waterwheels, as well as the sails on ships.
- Steam engines could be used as a reliable source of energy to operate the machinery in new factories. Goods were produced that were cheaper and more plentiful than ever before.
- New fuels were discovered — some for use in older technologies and some to power new technologies. Examples include the use of gas in homes for heating and lighting (replacing wood and coal), the use of petrol and diesel in cars, and the use of oil in ships and railway locomotives (replacing coal).
- The amount of energy needed to feed, clothe, house and transport people has increased astronomically over the centuries. This has led to concerns about where this energy will come from in the future and the environmental impact and sustainability of modern life.

Today, our demand for energy continues to increase. Most of this energy still comes from fossil fuels, which are burnt to produce heat energy and carbon dioxide. Carbon dioxide is the major contributor to the warming of Earth's atmosphere. This cannot be allowed to continue and, because of this, there is now much work and research being done to supply and use our energy in different ways. Examples of this include the following.

- The use of hydrogen as a fuel: This produces water instead of carbon dioxide when it is used. Hydrogen gas can be produced by solar or wind-generated electricity. This is known as 'green' hydrogen.
- The use of technologies such as solar cells: These convert sunlight directly into electrical energy.
- The use of new and better technologies to produce electrical energy from wind and moving water.
- New transport technologies such as electric vehicles (EVs): Currently, these have batteries that need recharging. If this can be done using solar-powered electricity, the vehicles will be almost pollution-free when in use. In the future, EVs may contain fuel cells that use the green hydrogen mentioned previously. These will also be almost pollution-free. Further, in heavy transport and shipping, ammonia (which can be made from hydrogen) may prove itself to be a 'fuel of the future'.
- Other new technologies such as artificial photosynthesis: Scientists are currently attempting to copy nature and use versions of photosynthesis to produce new, more environmentally friendly fuels.

1. What were the primary sources of energy used by early humans, and how did these sources shape their way of life?
2. How did the Industrial Revolution change the way energy was harnessed and used? Provide two examples.
3. What are two main environmental concerns related to the current use of fossil fuels?
4. Identify two modern technologies that aim to address sustainability concerns related to energy use.
5. Societal impacts of energy advancements:

How might new energy technologies impact society economically and environmentally?

Proposed scientific responses to socio-scientific issues impact on society and may involve ethical, environmental, social and economic considerations (VC2S8H03)

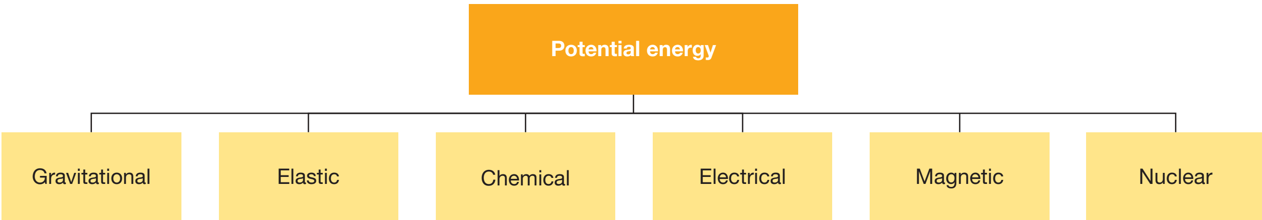
All forms of energy can be classified as either potential energy or kinetic energy. Potential energy is stored energy inside an object because of its position, shape or composition. Kinetic energy causes changes to objects or to the environment including changes to shape, position, brightness or temperature.

Many forms of kinetic energy, such as light, sound and thermal energy, are very easily observed. Potential energy has the 'potential' to make something happen, so is not easily observed.

8.2.2 Potential energy

Potential energy is the stored energy within an object. Potential energy can be created by many different situations including stretching or squashing an object, lifting an object above the ground or keeping unlike charges apart. Figure 8.4 lists the six different types of potential energy that will be explored.

FIGURE 8.4 Types of potential energy



Gravitational potential energy

Gravitational potential energy is created by a gravitational field. When an object is lifted above the ground or moved away from Earth's surface, it has the potential to fall back to Earth's surface as soon as it is released; hence, it is said to have gravitational potential energy. The heavier the object and the further it is from Earth's surface, the more gravitational potential energy it has (figure 8.5).

FIGURE 8.5 A diver diving off the 10-m board will have more gravitational potential energy than a diver on the 5-m board, where the pool surface is the 'ground'.

DISCUSSION

The amount of gravitational potential energy depends on the strength of the gravitational field. On the surface of the Earth the gravitational field is the same everywhere. However, the gravitational field is different on the Moon and on the other planets and moons in our solar system. On which planet do you think it would be easiest to gain gravitational potential energy? Where do you think it would be hard to gain gravitational potential energy? Make sure you can justify your answer.

Elastic potential energy

When the shape of an object is changed, it gains or loses elastic potential energy. A good example of this is the rubber band in a slingshot (figure 8.6). When the rubber band is pulled back, it gains elastic potential energy. The more the band is stretched, the more elastic potential energy it gains. While the rubber band is held stretched, it stores the elastic potential energy and has the potential to make something move as soon as it is released.

FIGURE 8.6 The stretched rubber in a slingshot stores elastic potential energy.

Chemical potential energy

An object is said to have chemical potential energy when the chemicals inside it have the potential to react and make something happen. One example of this is a battery. When the two terminals of a battery are connected, a chemical reaction takes place that results in the flow of electricity. Another example is the chemical potential energy in food and drinks as seen in figure 8.7. When eaten or drunk, food and drink release their stored chemical potential energy to our body so that we have energy to do things.

FIGURE 8.7 The chemical potential energy in foods and drinks is converted into the energy that we use to power our muscles.

Electrical potential energy

All substances are made up of positive and negative charges. When opposite charges are separated, they are said to have electrical potential energy, because as soon as they are released they are attracted together again. As the charges come together again, they release their electrical potential energy into other forms of energy. Static electricity is a good example of electrical potential energy. The charges on the plastic rod in figure 8.8 are pulling the charges in the flowing tapwater to the left. The electrical potential energy is holding the water in place. Inside a battery, the chemical potential energy is transformed to electrical potential energy before becoming electrical energy in a circuit.

FIGURE 8.8 The charges on the plastic rod are pulling the charges in the flowing tapwater to the left.

Magnetic potential energy

Magnetic fields provide another form of potential energy, called magnetic potential energy. It is easy to understand magnetic potential energy by playing around with some magnets. If you hold two magnets so that they are attracted to each other you will feel the pull of the magnets attempting to reach each other. If released, the magnetic potential energy will cause them to accelerate together.

Nuclear potential energy

The energy stored in the nuclei of atoms is called nuclear potential energy, because if the nuclei can be made to split or combine, a huge amount of energy has the potential to be released. An atomic bomb is an example of the energy released as a result of nuclear fission as seen in figure 8.9 (whereby a large nucleus splits into smaller fragments), while our Sun is an example of nuclear fusion (whereby two small nuclei combine to form a large nucleus, releasing large amounts of energy). Nuclear potential energy is also used in nuclear power plants and in the production of important chemicals for medical imaging and treatments.

FIGURE 8.9 The amount of nuclear potential energy that is released in nuclear reactions is so large it causes enormous explosions such as this one.

INVESTIGATION 8.1

Ice-cream stick energy

Elastic potential energy is energy stored in an object due to a change in its shape.
In this activity, you will make a basketweave pattern from some ice-cream sticks. When you make this, each time you add a new stick to the pattern a small amount of bending is required. This stores energy in the arrangement that you are producing.
You will then observe what happens when this energy is released.

Aim

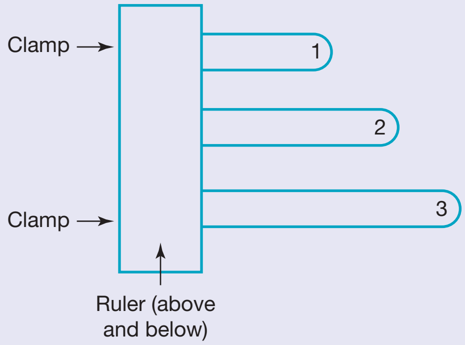
To demonstrate the storage and subsequent release of a form of potential energy

Materials

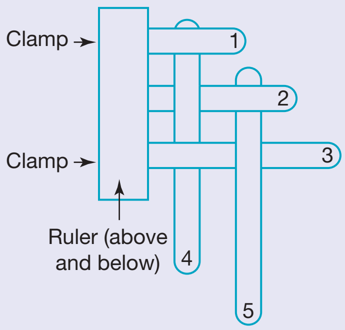
- a bundle of ice-cream sticks (If you can get tongue depressors, these are even better, as they are the same shape but more flexible.)
- clamp(s)
- two pieces of ruler (a 30-cm wooden ruler cut in half)
- video recorder (preferably one with a slow-motion option)

Method

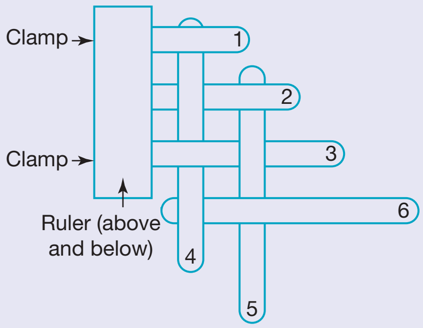
1. Make a starting piece as follows.
Place the ends of three sticks between the two ruler halves to make a sandwich. Make sure the sticks poke out to the *right*, as shown in the following diagram.
Next, clamp the two ruler halves tightly together. You may need to cut off the bits that poke out to the *left* of sticks 1 and 2 so that you can apply the clamps.



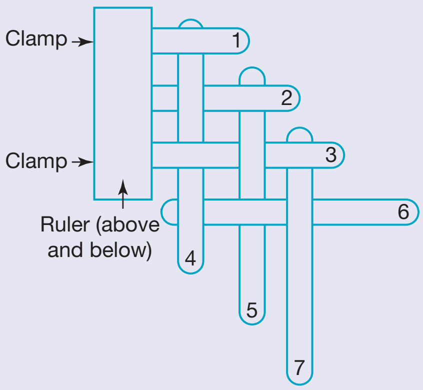
2. Now, take two more sticks (4 and 5) and add them as shown in the following diagram. Make sure that they go above and below sticks 1, 2 and 3 as shown.



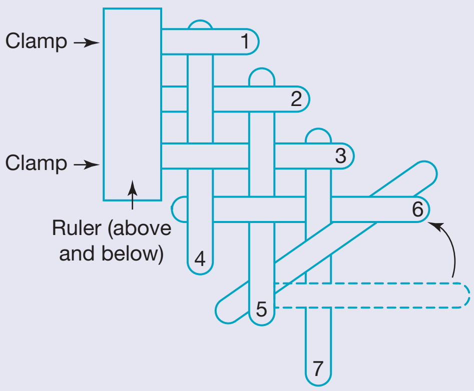
3. Add one more stick (6) as shown in the following diagram, once again making sure that it goes above and below as shown.



4. Add your next stick (7) as shown in the following diagram. At this stage, you should notice that a 'basketweave' pattern is starting to form. You may also notice that your construction is starting to feel 'springy'.



5. Continue adding sticks as in steps 3 and 4.
   Tip: The 'springyness' in your arrangement will probably become a problem for you. To overcome this, temporarily swing each new stick sideways, as shown in the following diagram, while you organise yourself to add the next stick. Make certain you return it to its proper position though before you add the next stick.



6. Keep building your chain until it has between 20 to 30 sticks in it and then carefully place it on a hard floor. Lay it as flat as you can. (You may need to put something under the clamps to help you with this!)
7. Let the last stick go and watch what happens. If you have a chance, record a video of what happens.
8. Have some more fun! Experiment with even longer chains. Maybe the class could make sections and you could add these together (carefully of course). You could try different surfaces or even go over some obstacles. You decide!

Results

Describe your observations, both while you were building your chain and when you let it off. Be sure to add any extra observations if you repeated this experiment. Remember that your observations are what your senses or instruments tell you. They are not explanations.

Discussion

1. What type of energy is stored in the ice-cream sticks when you bend each one to fit it into the pattern?
2. Explain why the arrangement feels springy, especially as you add more and more sticks.
3. When you let your arrangement off, there are three main energy transformations that take place. What are they?
4. Altogether, there are five types of energy involved in this experiment. Try to name them. (You may find that one of these is very hard to identify!)

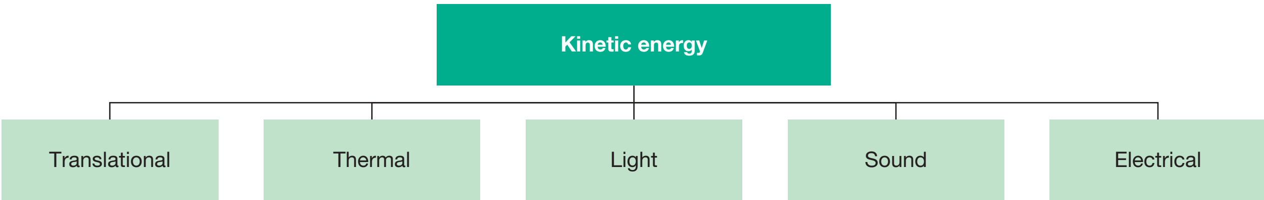
Conclusion

Summarise the findings for this investigation about the types of energy that were demonstrated.

8.2.3 Kinetic energy

Kinetic energy exists in many different forms and actively changes an object or the environment. All kinetic energy involves movement and change, whether it be the movement of objects from one place to another, the vibration of particles as thermal energy changing the temperature of a classroom, or other forms such as sound, light or electrical energy.

FIGURE 8.10 Types of kinetic energy



Translational kinetic energy

Any object that is moving has translational kinetic energy as it is changing position. The heavier an object and the faster it travels, the more translational kinetic energy it possesses. A person walking, a ball rolling or a car being driven are some examples of translational kinetic energy.

FIGURE 8.11 The blades in wind turbines contain large amounts of translational kinetic energy when they rotate.

Thermal energy

Thermal energy, more commonly called heat energy, flows from hotter objects to cooler objects. Thermal energy makes the particles inside objects vibrate or move. In hotter objects the particles have bigger vibrations, with the particles moving further and more quickly. In cooler objects the particles have smaller vibrations, with the particles moving a small distance and more slowly. These vibrations, and therefore the amount of thermal energy in an object, can be determined by measuring the temperature of an object. Thermal energy is considered a form of kinetic energy as it changes the temperature of objects by moving from a hotter object to a colder object.

FIGURE 8.12 When you touch a cold object you transfer thermal energy to it, heating it slightly.

Light energy

Light energy is the energy of the **visible spectrum**, a small part of the **electromagnetic spectrum**. Other types of **electromagnetic radiation** are associated with other types of energy, including infrared light and thermal energy. Examples of light energy include light from the Sun, light bulbs, lamps, torches and flames. Light is a form of kinetic energy as it can move from one place to another, changing the brightness of the environment.

FIGURE 8.13 Hot objects release radiant energy in the form of light.

Sound energy

Sound involves the vibration of particles in the air or another medium. It is a form of kinetic energy as the movement of particles changes the amount of sound in an area. A sound source — such as an instrument or your voice — contains an object that vibrates, causing the nearby particles in the air to vibrate. You are able to hear some sounds because your ear can detect the vibration of particles, sending a message to your brain, which tells you the type of sound you are hearing.

FIGURE 8.14 The strings on a violin vibrate, sending sound waves through the air.

ACTIVITY: Musical instruments

Musical instruments produce sound in different ways — strings vibrate, wind instruments use breath, woodwinds rely on reeds and percussion makes sound when struck.

Research one instrument and answer these questions:
- How does it produce sound — string, breath, reed, strike or another method?
- Which orchestra section does it belong to?
- How does it make louder or softer sounds?
- How does it create different notes?

Present your findings in a poster or slide deck presentation for the class.

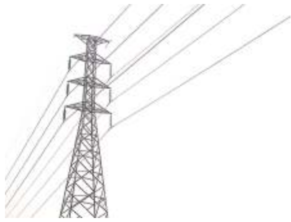
Electrical energy

Electrical energy, which is different from electrical potential energy, is a form of kinetic energy. When electric charges are moving through a circuit, it is a form of kinetic energy called electricity. Electricity is used to power most of your favourite devices, such as your television, your smart phone and your computer. Electrical potential energy is normally transformed into electrical energy. An example of this is in lightning, where separated charges in the clouds and on the surface of the earth store electrical potential energy. When the amount of electrical potential energy becomes too large, electrical energy in the form of a lightning bolt forms from the stored electrical potential energy. Light, sound and thermal energy are created as the electrical energy moves through the atmosphere.

FIGURE 8.15 Electrical energy powers all electrical devices, such as this tablet.

TABLE 8.1 A summary of the types of energy

Potential energy (stored energy that, when released, is converted to forms of kinetic energy)	Kinetic energy (often converted from potential energy, these forms of energy are connected to movement and change)
Gravitational — potential energy of an object elevated above the ground 	Translational kinetic — energy possessed by objects that are moving 
Elastic — energy stored by an elastic object that is stretched, squashed or bent, such as a spring or rubber band 	Thermal — energy that causes objects to increase or decrease their temperature 

Chemical — energy stored in chemicals that is released in a chemical reaction		Light — energy from light bulbs and the Sun, which changes the brightness of an area.	
Nuclear — energy stored in the nucleus of atoms that can be released slowly, such as in a nuclear reactor, or quickly, such as in a nuclear explosion		Sound — energy carried by vibrating particles and detected by the ear	
Electrical potential — energy stored by the build-up of charge		Electrical — energy provided by the movement of electrons	
Magnetic — energy stored in magnets or metals placed in a magnetic field			

8.2 Activities

learnon

8.2 Quick quiz on

8.2 Exercise

Select your pathway

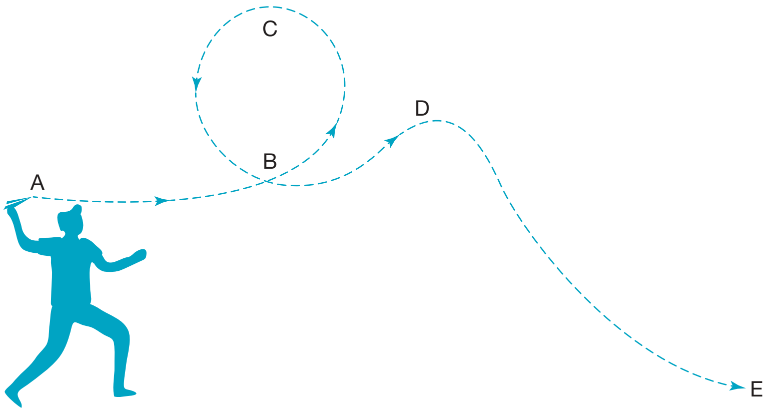
LEVEL 1	LEVEL 2	LEVEL 3
2, 3, 6	1, 5, 7	4, 8, 9

Remember and understand

1. Classify the following as examples of potential energy or kinetic energy:
   - An athlete running
   - A spring being squashed
   - Sound coming from a speaker
   - A skydiver about to jump from an aeroplane
   - The light emitted from a light globe.
2. **List** five types of potential energy.

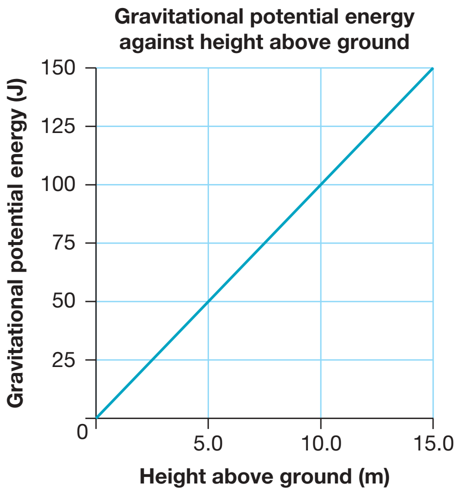
Apply and analyse

3. For each of the following statements:
   i. determine whether it is true or false
   ii. **justify** your response.
      a. As a ball is thrown up into the air, it gains more gravitational potential energy the higher it moves.
      b. The energy in a stretched elastic band is a type of kinetic energy.
      c. Only springs and rubber bands can have elastic potential energy.
      d. Sound is a type of kinetic energy.
4. **Identify** four types of energy that are present during a lightning strike.
5. **Explain** why a high diver has gravitational potential energy.
6. MC A student throws a paper aeroplane and it follows the path shown by the dotted line. Consider the points in its flight labelled A, B, C, D and E.
   At which point does the paper aeroplane have the greatest gravitational potential energy?
   A. Point A
   B. Point B
   C. Point C
   D. Point D
   E. Point E



Evaluate and create

7. SI **Explain** the different types of energy found in a moving car. **Describe** where each type of energy is located and how it contributes to the car's movement. Make sure to include at least three different forms of energy.
8. SI Reflect on the different forms of energy at school every day. Write a tally of all the times you come across them. Present your results in a bar chart.
9. SI The graph shows the relationship between gravitational potential energy (J) and height above the ground (m) of a 1 kg ball thrown into the air.
   a. **Identify** how much gravitational potential energy the ball has when it is 10 m above the ground.
   b. **Identify** at what height above the ground the ball is when it has 75 J of gravitational potential energy.
   c. **Describe** the relationship between height and gravitational potential energy shown in this graph.
   d. If gravitational energy is directly proportional to the mass of an object, **construct** a graph showing the gravitational potential energy versus height for a ball with mass 2 kg thrown into the air.



Answers and sample responses are available in your digital formats.

LESSON 8.3 Energy transfer — conduction, convection and radiation

LEARNING INTENTION

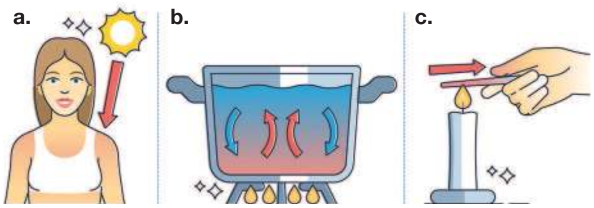
In this lesson you will describe the different ways that thermal energy is transferred in solids, liquids and gases, using particle models to explain conduction, convection and radiation.

8.3.1 What is energy transfer?

Energy can be transferred from one object to another. This is called energy transfer. In thermal energy transfer, heat always moves from a hotter object or region to a colder one. There are three main ways this can happen:

- **Radiation** transfers heat through space using waves, such as sunlight warming skin.
- **Convection** moves heat through fluids, such as boiling water rising and falling in a pot.
- **Conduction** transfers heat through solids by particle vibration, such as a metal rod heating from one end to the other.

FIGURE 8.16 A comparison of the three main methods of heat transfer: **a.** radiation, **b.** convection, and **c.** conduction



Radiation

Radiation is the transfer of energy by electromagnetic waves, primarily infrared radiation, but also visible light and other forms of radiation. Unlike conduction and convection, radiation does not require particles to transfer heat, meaning it can travel through empty space.

For example, when you feel the warmth of the Sun on your face on a cool day, that heat has travelled across space, which is a vacuum, entirely through radiation. Similarly, when sitting by a campfire, you feel its warmth even without directly touching it — because heat energy is radiating outwards from the flames.

Convection

Convection is the transfer of heat in fluids — liquids and gases — through the movement of particles. Unlike conduction, where heat is passed from particle to particle, convection occurs when warmer, less dense fluid rises while cooler, denser fluid sinks. This creates a continuous circulation known as a convection current, which helps distribute heat more evenly.

For example, in boiling water, heat from the stove warms the water at the bottom. As it absorbs energy, the water becomes less dense and rises. Meanwhile, cooler, denser water moves downwards to take its place. This cycle repeats, forming convection currents that gradually spread heat throughout the entire liquid.

Conduction

Conduction is the transfer of thermal energy through a solid, particularly in metals, which are excellent conductors. It occurs when particles in the hotter region of the solid vibrate more rapidly and transfer their energy to neighbouring particles.

For example, when a metal spoon is placed in a hot cup of tea, the particles in the spoon that are in direct contact with the tea gain energy. These energised particles then collide with adjacent particles, passing the heat along the length of the spoon, making it warm.

KEY IDEA

- Radiation can occur in a vacuum and is affected by surface colour and texture. Dark, matte surfaces absorb and emit radiation more effectively than shiny, light surfaces.
- In convection, warm particles move and carry energy with them, forming a circulating flow known as a convection current.
- Metals are good conductors because their particles are closely packed and include free-moving electrons, which help spread energy quickly.

INVESTIGATION 8.2

How does heat transfer from your hand to different materials?

Aim

To observe how heat is transferred from your hand to different materials and to compare the rate of heat transfer

Materials

- thermal imaging camera or heat-sensitive film
- metal object (e.g. spoon or ruler)
- plastic object (e.g. ruler or lid)
- timer or stopwatch
- gloves or paper towel (for control comparison)

Method

1. Place the metal and plastic objects on a table so they are at room temperature.
2. Place your hand flat on the metal object for 10 seconds.
3. Immediately use the thermal imaging camera or heat-sensitive film to observe and record the heat transfer.
4. Repeat the process with the plastic object.
5. Optionally, try placing your hand on a piece of paper or wearing a glove to compare insulating effects.

Results

Sketch or capture the thermal images or describe the colour change in the film. Which object became hotter faster?

Discussion

1. Which material conducted heat more quickly? Explain why.
2. How could this be applied in real-world product design (e.g. saucepans, handles)?

Conclusion

Summarise your findings. Include a comparison of how quickly heat transferred from your hand to the metal and to the plastic object.

INVESTIGATION 8.3

What do convection currents look like in water?

Aim

To observe how convection currents form and move in heated water

Materials

- clear glass container (e.g. beaker or jar)
- cold water
- food colouring or potassium permanganate crystals
- heat source (e.g. hotplate or heat mat)
- dropper or spatula

Method

1. Fill the container with cold water and let it settle.
2. Carefully place the container on the heat source and turn it on to a gentle setting.
3. Place a drop of food colouring or a few crystals at the bottom centre of the container.
4. Observe the movement of coloured water as the water heats up.
5. Record your observations.

Results

Draw what you saw, especially how the coloured water moved. Use arrows to show direction.

Discussion

1. Why does the coloured water rise?
2. What causes the cooler water to sink?
3. How does this help us understand how air or ocean currents move?

Conclusion

Summarise your findings. Include a description of the pattern made by the coloured water and explain how this pattern shows that warm water moves differently to cool water.

8.3 Activities

learnon

8.3 Quick quiz on

8.3 Exercise

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3	4, 5, 8	6, 7, 9, 10

Remember and understand

1. MC Which of the following is an example of conduction?
   A. Warm air rising above a heater
   B. A metal spoon getting hot in soup
   C. A person standing in sunlight
   D. A hot cup giving off steam
2. MC What type of energy transfer does not need particles to travel through?
   A. Conduction
   B. Convection
   C. Radiation
   D. Friction
3. **Define** conduction and give one example from everyday life.
4. **Describe** how convection moves thermal energy through liquids.

Apply and analyse

5. **Explain** why saucepans are made of metal but have plastic handles.
6. **Explain** which method of energy transfer would work best in space.
7. **Describe** the energy transfer methods that occur when a person warms their hands by a campfire. **Explain** how each method contributes to the heating.
8. A student places sheets of black and white paper under a lamp. The black paper gets hotter. **Explain** why.

Evaluate and Create

9. Design a simple classroom demonstration that shows convection. What materials would you use and what would you expect to see?
10. **Evaluate** how energy transfer methods are used in a camping situation (e.g. campfire, metal pot, sleeping bag).

Answers and sample responses are available in your digital formats.

LESSON 8.4 Energy transformations and efficiency

LEARNING INTENTION

In this lesson you will:

- understand how energy is transformed from one form to another in simple systems
- identify energy that is not useful
- analyse systems for energy efficiency using flow and Sankey diagrams.

8.4.1 Energy can be transferred

Energy transfers happen all around you every day, although many energy transfers are hidden from sight. In an energy transfer, the energy type does not change.

When a tennis racquet hits a tennis ball, there is an energy transfer. Some of the kinetic energy of the tennis racquet is given to the tennis ball, the tennis racquet slowing down while the tennis ball changes direction. When a piece of fruit is eaten, the chemical potential energy of a piece of fruit transfers to the chemical potential energy of a person. The piece of fruit loses its chemical potential energy while the person gains chemical potential energy to use during the day. The kinetic energy of the wind makes a wind turbine start turning by transferring kinetic energy from the wind to the turbine.

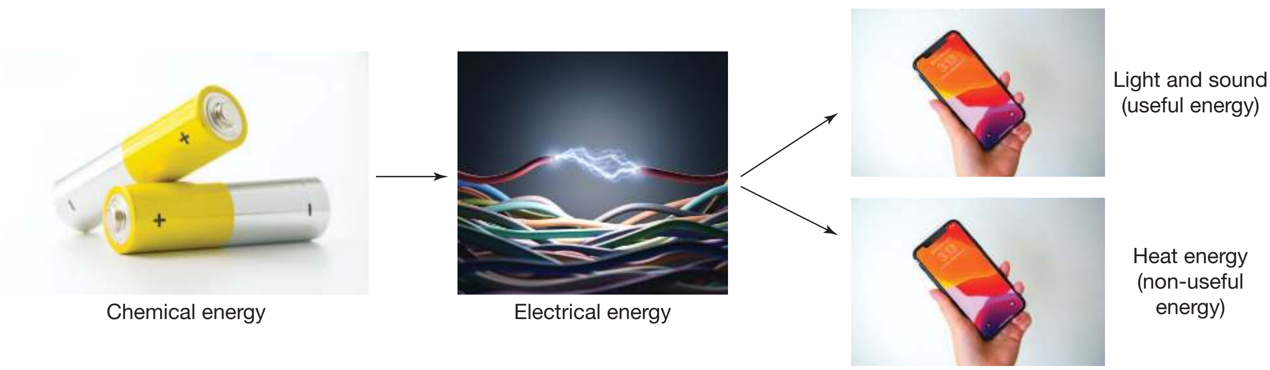
FIGURE 8.17 Energy transfer during a tennis game

8.4.2 Energy flow diagrams

Energy flow diagrams are a visual way to show the energy transformations occurring in a system. In an energy flow diagram, an arrow is drawn from the energy input to the **useful energy** output (see figure 8.18). Energy flow diagrams make it easier to see any energy transfers and transformations that are happening, compared to writing out these transfers and transformations in a list.

It is usual for there to be more than one energy output, but only the useful forms of energy are listed in energy flow diagrams. In the example given in figure 8.18, heat would not usually be listed as it is not a useful form of energy for a mobile phone.

FIGURE 8.18 An example of the energy transformations occurring in a mobile phone are shown in the energy flow diagram.



8.4.3 Sankey diagrams and non-useful energy

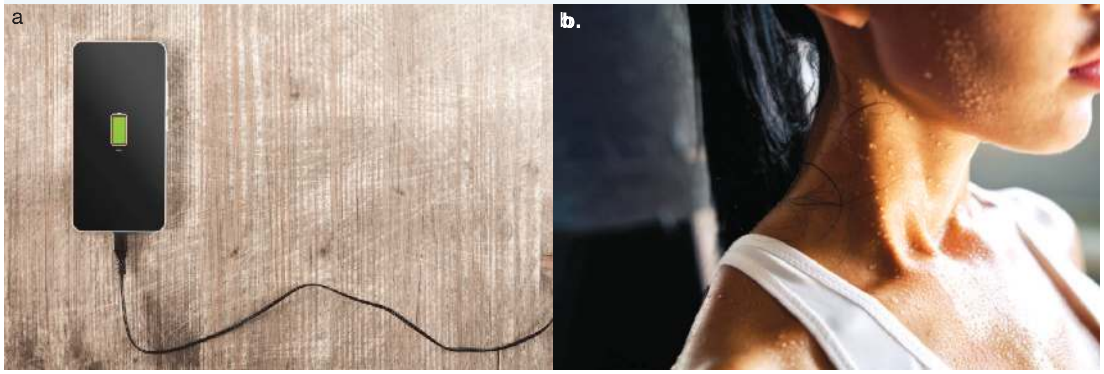
Every energy transfer and transformation is a process that changes the energy involved. Most of the energy is converted into useful energy, but some is converted into forms of energy that are wasted or not so useful. None of the wasted energy is actually lost; the energy has just been transformed into less useful forms of energy. Table 8.2 shows some examples of energy conversion by electrical appliances and the less useful forms of energy, or energy 'losses', that occur.

TABLE 8.2 Energy conversion by electrical appliances

Appliance	Electrical energy usefully converted to …	Electrical energy wasted …
Microwave oven	thermal energy of food	heating air in the oven, plates and cups, etc.
Television	light and sound	heating the television and the surrounding air
Hair dryer	thermal energy and kinetic energy of air	as sound
Electric cooktop	thermal energy of food	as light and heating the surrounding air

This loss of useful energy is also apparent when you squeeze the handbrakes of a bicycle — not all the energy you transfer to the brakes is used to stop the bicycle. Much of the energy is converted to thermal energy and is released to the surrounding air as heat. The same idea applies to the electrical energy transferred to a laptop when it is charging. Not all the electrical energy actually reaches the laptop; some is transformed into thermal energy in the black transformer box. Another example of energy 'loss' occurs when you drop a tennis or cricket ball. It never bounces back to its original height because some energy is lost as heat and sound. On a larger scale, energy 'loss' occurs in power stations, where the fuel, falling water, solar energy or other energy source is used to produce electricity. Some of the energy of the source is transformed to heat, warming the power equipment, the surrounding air and the water used as coolant. The 'loss' of useful energy is unavoidable.

FIGURE 8.19 Heat is a by-product in a number of energy transformations. **a.** When recharging electronic devices, not all the electrical energy is converted into chemical energy. **b.** When you exercise you get hot as your muscles convert the chemical energy into kinetic energy. This is why you perspire — to help cool you down.



Some types of lighting waste more energy than others. Old-fashioned incandescent light bulbs convert more energy to wasted heat than to light. They emit light only when the **filament** inside gets white hot. Fluorescent lights and LEDs waste substantially less energy. Almost all of the electrical energy is converted to light, so you use much less energy to produce the same amount of light than you would using an incandescent bulb.

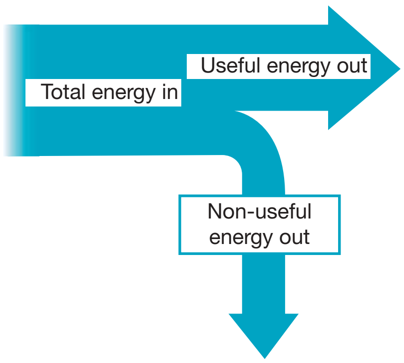
The most common non-useful energy produced by an energy transformation is thermal energy. However, thermal energy can be very useful; it is needed to heat homes when the weather becomes cold, for transport, to cook food, to manufacture metal, ceramic or wood products, to generate fire and in many other situations.

On the other hand, some situations require energy without unwanted heat. When transferring chemical potential energy from your body into kinetic energy, any thermal energy produced is not useful. Inside a computer, electrical energy is converted to light energy and sound energy, which is useful; however, the thermal energy produced is not useful and can prevent computers from working properly if the thermal energy cannot escape.

Other common types of non-useful energy include sound energy, light energy and even kinetic energy. Depending on the situation, any type of energy could be non-useful and therefore 'lost' energy.

A **Sankey diagram** is a diagram showing the amount of useful vs non-useful energy produced in an energy transformation. An example of a Sankey diagram is shown below.

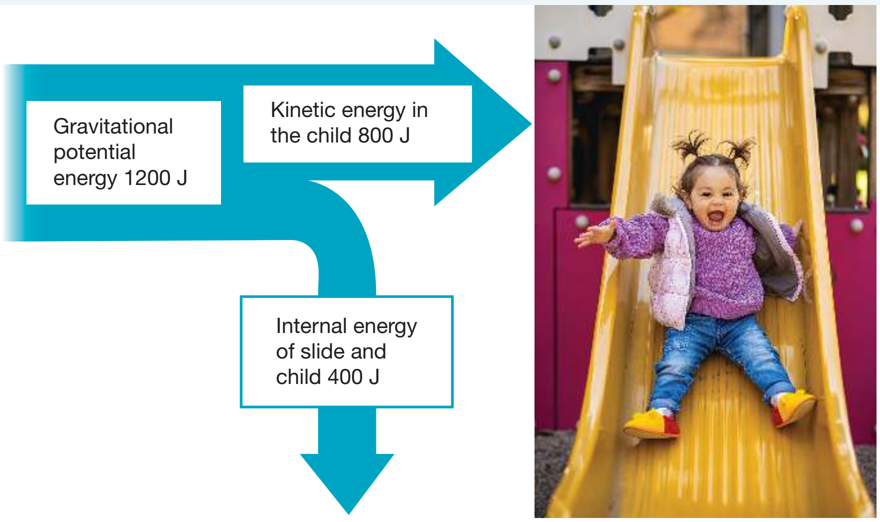
FIGURE 8.20 A general Sankey diagram showing the input energy and both the useful and non-useful output energies.



A Sankey diagram is read from left to right. The width of the arrow on the left shows the amount of energy at the start of the transformation. This energy is then split into the amount of useful energy produced by the transformation, shown moving straight across the page, and the amount of non-useful energy produced by the transformation, shown moving down the page. The width of the useful and non-useful arrows shows the amount of energy of each type produced by the transformation. For the Sankey diagram above, double the amount of useful energy is produced compared to non-useful energy. The arrow going to the right is double the width of the arrow pointing down.

Energy is measured in joules (J). A Sankey diagram for a specific situation will normally include the energy type and amount in joules. This is shown in the Sankey diagram below for a child sliding down a plastic slide at a playground.

FIGURE 8.21 A Sankey diagram of a child sliding down a plastic slide in a playground. The input and output energies are labelled and the amount of each type of energy is shown in joules. This process is quite efficient.



Sankey diagrams can also help determine the **efficiency** of an energy transfer or transformation. In an efficient process, most of the energy produced is useful. In an inefficient process, most of the energy produced is non-useful.

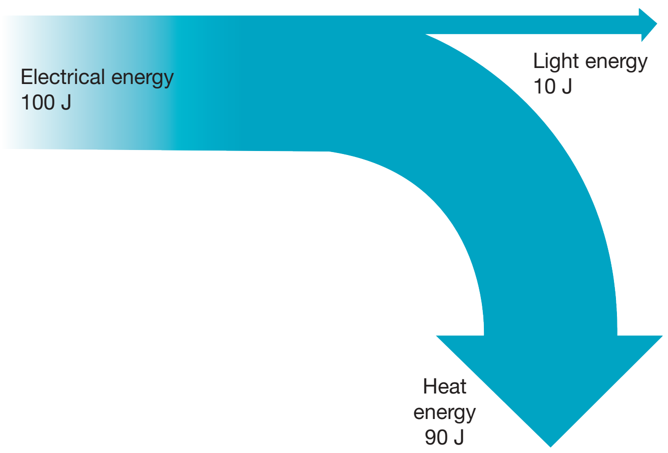
The example of a child going down a plastic slide shown in the Sankey diagram above is quite efficient. More useful than non-useful energy is produced.

The Sankey diagram in figure 8.22 shows an inefficient process, as most of the output energy is non-useful. This process happens in your body when you jump. Most of the chemical energy stored in your body from the food you have eaten is transformed into thermal energy when your muscles move during the jump. Very little of the energy is transformed into gravitational potential energy from the height you reach.

FIGURE 8.22 A Sankey diagram of energy transformations happening when a person jumps. The input and output energies are labelled and the amount of each type of energy is shown in joules. This process is quite inefficient.

Old, incandescent light bulbs are also very inefficient. A Sankey diagram of an incandescent light bulb is shown in figure 8.23. Very little of the electrical energy entering the light bulb is transformed into light energy, the type of energy people want from a light bulb. Most of the electrical energy is transformed into heat, which is not useful when you are trying to read a book or get dressed on a winter morning.

FIGURE 8.23 A Sankey diagram showing energy transformations in an incandescent light bulb, an inefficient process.



CASE STUDY: Comparing the energy efficiency of light bulbs

In old-fashioned incandescent light bulbs, electricity passes through a thin filament in the bulb, which is filled with nitrogen or argon gas, causing it to glow white hot. The light is a useful form of energy, but about 90 per cent of the electrical energy is wasted as heat. Compact fluorescent lights (CFLs) offer a more energy-efficient form of lighting, but light-emitting diodes (LEDs) are even more efficient.

FIGURE 8.24 LEDs are more efficient than the alternatives. Note that the figures quoted are approximate.

SCIENCE INQUIRY: Solar cells — harnessing energy from the Sun

One important application of efficient energy use is in solar technology. Scientists use models and testing to improve the design of solar cells, helping to meet energy needs more sustainably.

A solar cell, also known as a photovoltaic cell, is a device that converts light energy from the Sun into electrical energy. When sunlight strikes the semiconductor layer inside the solar cell, it knocks electrons free from their atoms.

If the solar cell is connected to an **electrical circuit**, these free electrons flow, generating electricity that can power devices or be stored in batteries for use when sunlight is unavailable, such as at night.

Modern solar cells are becoming increasingly efficient. Most residential solar cells convert about 20 per cent of the Sun's energy into usable electricity, while newer designs are being developed to improve this efficiency further.

Multiple solar cells can be connected together to form a photovoltaic module, also called a solar panel. Several panels can be wired together to create a solar array, which can generate enough energy to power homes, businesses or even entire communities.

Solar energy systems are an important step towards renewable energy solutions, reducing greenhouse gas emissions and dependence on fossil fuels.

FIGURE 8.25 Solar arrays are made up of modules, which are made up of cells.

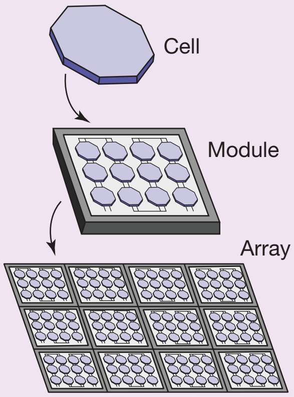


FIGURE 8.26 Solar arrays are often placed on roofs to provide cheap, sustainable energy.

1. What type of energy does a solar cell convert into electrical energy?
2. If a solar cell is 20 per cent efficient and receives 1000 joules of energy from the Sun, how much energy is converted into electricity?
3. Why are batteries often used with solar panels?
4. What is the term for connecting multiple solar panels together to generate more energy?
5. What are two environmental benefits of using solar panels for energy production?

Data and information can be organised and processed by selecting and constructing representations including tables, graphs, keys, models and mathematical relationships (VC2S8I04)

8.4.4 Aboriginal and Torres Strait Islander Peoples and fire

Fire was, and still is, a very important tool used by Aboriginal and Torres Strait Islander Peoples. It is used for cooking, for warmth, for hunting, for smoking ceremonies and, very importantly, to manage the landscape. It also holds a deep spiritual meaning for Aboriginal and Torres Strait Islander Peoples. Many stories are told and passed on around campfires, either verbally or through various songs and dances. Fire is regarded as a friend and is a very important part of their culture. Fire-starting is an important feature in many Aboriginal and Torres Strait Islander Peoples ceremonies.

Figure 8.27 Striking a match against the box's rough surface creates friction, igniting the phosphorus and producing a flame.

Transforming energy to start a fire

The most common way that fire is started anywhere in the world today is through friction matches. Striking a match along the side of its box produces **friction** and thermal (heat) energy. This then ignites a small phosphorus head. When this and the wood that it is attached to ignite, chemical energy in the wood and phosphorus are transformed into thermal energy.

The energy transformations involved may be summarised as follows:

Kinetic energy (by striking) → Thermal energy (by friction) → Chemical energy (in phosphorus and wood) → Thermal energy (heat from burning match)

This sequence is an adaptation of methods that were traditionally used by many Indigenous peoples around the world. Most methods use the friction created by rubbing one piece of wood against another piece of wood. This process creates a lot of heat. The heat increases the temperature of the wood so that it is high enough to start burning. Without the phosphorus used in modern matches, Aboriginal and Torres Strait Islander Peoples needed to reach higher temperatures to start a fire. This requires much more mechanical energy than striking a match.

Across Australia, Aboriginal and Torres Strait Islander Peoples used three different approaches to create fire using the friction between two pieces of wood.

A less widely used method involves striking stones such as flint or ironstone together to make sparks. These methods make use of the thermal and light energy normally classified as 'non-useful' energy. In most situations involving friction, the thermal or light energy produced is a problem. Aboriginal and Torres Strait Islander people found a way to make this energy useful when starting fires.

The *fire drill* method involves a round stick (the drill) and a flat piece of wood (the hearth). A small hole is made in the hearth to keep the drill in position. A small notch is also often cut into the side of this hole so that the hot sawdust produced can fall out onto flammable dried grass (this is called **tinder**). The drill is then rubbed back and forth between the palms to move the drill while the hearth stays still. This generates friction between the drill and the hearth. Small amounts of sand are often added to increase the friction. Once the hot sawdust falls onto the tinder and starts smouldering, a person blows gently on the tinder to produce a flame.

FIGURE 8.28 Cultural fire management

This process involves a number of energy transfers and transformations. Kinetic energy from the hands is transferred to kinetic energy in the rotating stick. This energy is then transformed to thermal energy through friction, raising the temperature of the sawdust produced. This sawdust eventually reaches a temperature at which it starts to smoulder. At this point, the chemical energy in the sawdust begins to be transformed into more thermal energy. Finally, this thermal energy is transferred to the tinder material. The chemical energy within this material is then transformed into even more thermal energy when it begins to burn. The key transformations involved are:

Kinetic energy (in rotating drill)	→	Thermal energy (by friction)	→	Chemical energy (in sawdust)	→	Thermal energy (heat from burning tinder)

Other methods used by Aboriginal and Torres Strait Islander Peoples to create fire are similar to the fire drill method. Instead of making the drill rotate in the same spot on a hearth, the *fire plough* method moves the drill quickly backwards and forwards along a groove in the hearth to generate friction. The heat created from the friction lights tinder lying in the groove.

The *fire saw* method moves the drill piece in a rapid back and forth motion across a notch in the second piece of wood, mimicking the action of sawing through the second piece of wood. This creates friction and heat, which can ignite tinder lying beneath the notch.

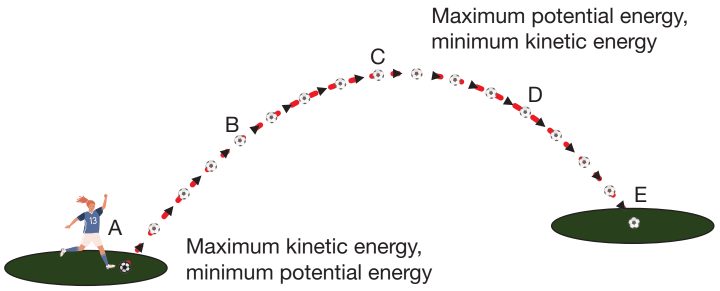
These methods worked best with different types of wood from different trees. In areas to the north and along the coast of Australia, the fire drill method was the most commonly used to start fires. In north-western Australia, the fire plough method was more common due to the different trees and plants growing there. Aboriginal groups living in inland Australia mostly used the fire saw method.

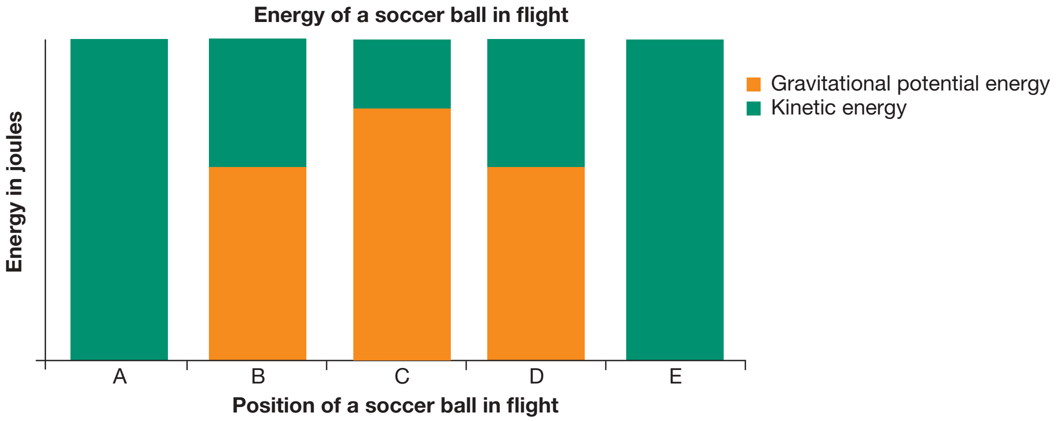
In many parts of South Australia, the trees and plants did not produce the right types of wood to use any of the friction methods of creating fire. Instead, rocks were struck against each other to create sparks. This only works with certain types of rock, including flint and pyrites, which generate a lot of friction and heat when hit against each other. These types of rocks are common in South Australia.

8.4.5 Lifting and dropping objects

As a ball moves through the air, gravitational potential energy and kinetic energy are constantly changing. Use the diagram in figure 8.29 to identify where each type of energy is at its maximum.

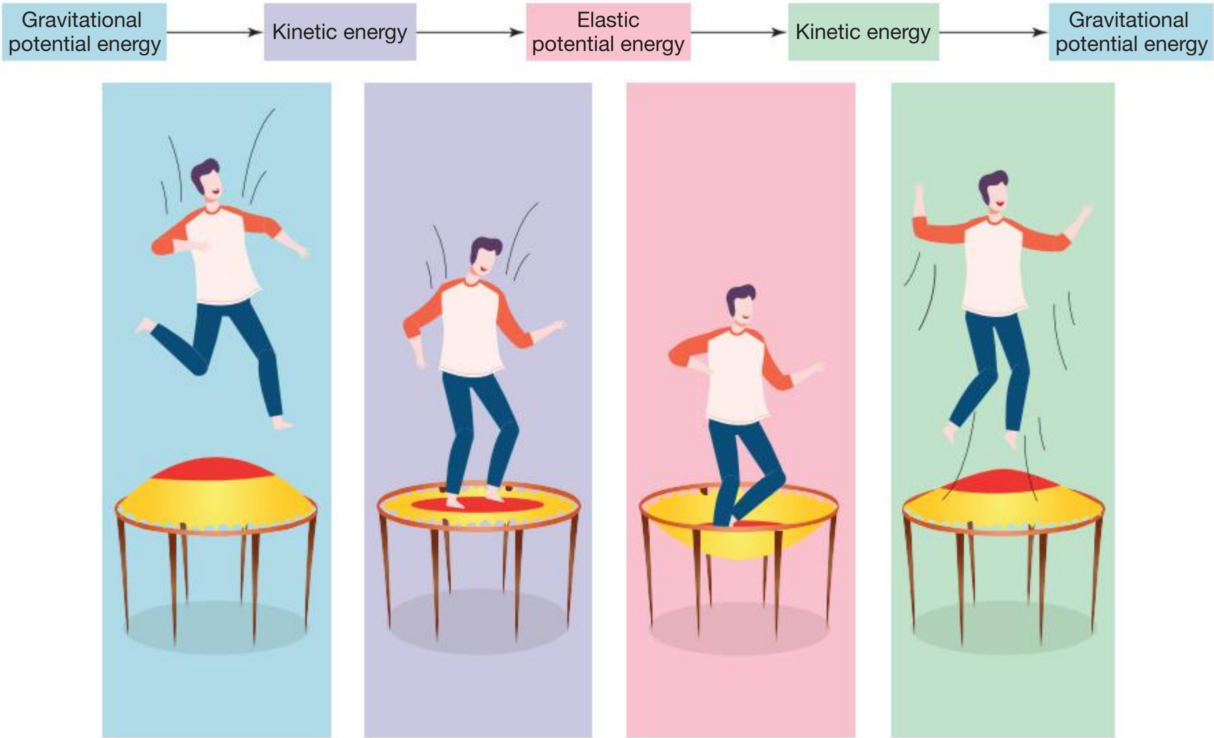
FIGURE 8.29 The energy transformations of a soccer ball in flight. Note: At the highest point (C), the ball still has some kinetic energy because it is moving horizontally.





A trampoline works in a similar way, but also involves elastic potential energy. Use the diagram in figure 8.30 to identify when gravitational, kinetic and elastic potential energy are each at their greatest. Think about how the energy changes as the person falls, compresses the mat and is launched back into the air.

FIGURE 8.30 Energy conversions that occur when bouncing on a trampoline



1 At the very top of a jump, the bouncer is momentarily stopped — he has no kinetic energy. But he does have gravitational potential energy due to his height above the trampoline. As the force of gravity pulls the bouncer down, some of his potential energy is transformed into kinetic energy.

2 As the bouncer strikes the trampoline, his kinetic and gravitational potential energy are transferred to the trampoline's surface and springs. The energy is momentarily stored in the springs. It is called elastic potential energy.

3 At this point, the bouncer pushes off the trampoline. The elastic potential energy is transformed back into kinetic energy and some gravitational potential energy.

4 As the bouncer rises again, his kinetic energy is transformed into gravitational potential energy again. At the top of the jump, the bouncer has no kinetic energy, just gravitational potential energy.

8.4.6 Playing sport

Energy transfer from one object to another object is usually easy to observe because one or both objects slow down, speed up or change direction. A transfer of energy to or from an object can also cause the object to start or stop spinning. Some examples of energy transfer from object to object in common sports are explained here.

FIGURE 8.31 In a golf swing, energy transfers from your muscles into the club and finally into the ball.

- When the golfer in figure 8.31 swings his club, energy is transferred from his body to the club. When the club strikes the ball, most of its energy is transferred to the ball to make it move. The ball gains both kinetic energy, some of which transforms into gravitational potential energy at it rises above the ground, as a result of the transfer. The golf ball might also spin.
- When a weightlifter lifts weights into the air, the weightlifter transfers kinetic energy from their body to the weights, which then transforms to give the weights additional gravitational potential energy.

- The guernseys of AFL and AFLW players contain pockets to hold tracking devices. These tracking devices record a player's movements during a game. The devices are powered by small batteries. The chemical energy in the cell or battery is transferred to an electric charge, causing it to move around an electrical circuit. The kinetic energy of the moving electric charge is then transformed into electrical energy to operate the tracking device.
- When a tennis ball hits the racquet strings, its kinetic energy is temporarily stored as elastic potential energy in the squashed ball and the racquet strings. Most of this is transformed back to kinetic energy as the ball rebounds, along with the extra energy that has been added from the player's moving arm. A small amount of energy is transformed into heat.
- In tenpin bowling (see figure 8.32), a heavy bowling ball strikes pins, which are themselves quite heavy. These pins then strike other pins, resulting in the pins being knocked over. In energy terms, the object of the game is to transfer kinetic energy from the bowling ball to the first pins that are struck. As these fly off, their kinetic energy and the remaining kinetic energy in the ball itself are transferred to other pins as they collide. This results in the pins being knocked down.
- In billiards and snooker, a moving cue ball strikes a stationary target ball. After they collide, the target ball will move off with a certain speed, while the cue ball will be moving slower or may even stop. Exactly what happens depends on the angle at which they collide. All the energy involved here is kinetic energy.

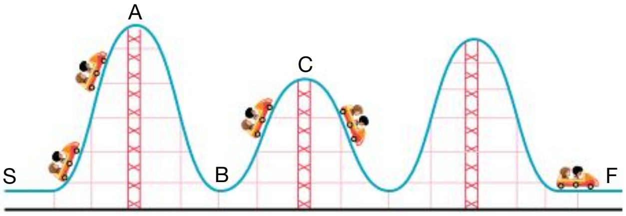
FIGURE 8.32 Tenpin bowling involves transferring energy from a bowling ball to the target pins.

8.4.7 Riding a roller-coaster

Roller-coasters are a great example of how energy transforms between different forms. At the start of the ride, an electric motor pulls the car up to the highest point. As the car rises, it gains gravitational potential energy.

When the car begins its descent, this potential energy is converted into kinetic energy — the car speeds up. As the car goes up and down, energy keeps changing back and forth between potential and kinetic forms.

FIGURE 8.33 A simple roller-coaster. Notice that the cars never return to their starting height.



Not all of the energy stays useful. Some energy is transformed into thermal energy and sound due to friction with the rails. This is why the car never returns to its original height.

At the end of the ride, the car still has some kinetic energy. Brakes on the track help convert this remaining energy into heat to bring the car safely to a stop.

ACTIVITY: Designing a roller-coaster

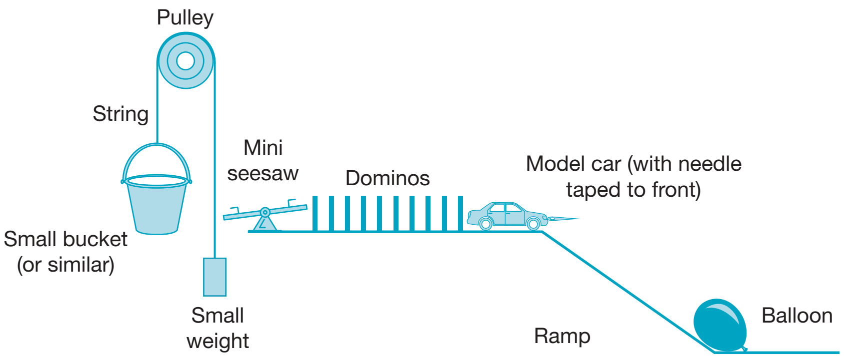
Use the roller-coaster diagram (figure 8.33) to label:
- a point with maximum gravitational potential energy
- a point with maximum kinetic energy
- a section where energy is being lost as heat or sound
- a point where the car is slowing down.

8.4.8 Rube Goldberg machines

A **Rube Goldberg machine** is a deliberately complex device that performs a simple task through a series of connected actions. These machines often use everyday materials and rely on a sequence of energy transfers and transformations. You may have seen them in videos, games such as Mousetrap® or in science exhibitions.

Figure 8.34 shows one example where a chain reaction is designed to pop a balloon. Your task is to design and build your own version of a Rube Goldberg machine, using your understanding of how energy is transferred and transformed between steps.

FIGURE 8.34 A Rube Goldberg machine designed to burst a balloon with water



INVESTIGATION 8.4

Building a Rube Goldberg machine

Aim

To build a Rube Goldberg machine and identify the energy changes that occur throughout the process

Materials

Choose simple, safe items available in the classroom or at home, for example: marbles, toy cars, ramps, cardboard, dominos, string, balloons, cups, rubber bands.

Method

1. Sketch your machine design. It should complete a task (e.g. burst a balloon, ring a bell, topple a tower).
2. Make a list of materials and collect what you need.
3. Build the machine one section at a time. Test each section before adding the next.
4. Run the machine and observe the energy transfers and transformations that occur.

Results

Draw a neat, labelled diagram of your machine. Include arrows or labels showing where energy is transferred or transformed.

Discussion

1. What changes did you make from your original design, and why?
2. Identify at least three energy transformations or transfers in your machine.
3. Some real machines are complex out of necessity. Can you give two examples of machines that need to perform a task in a complicated way?

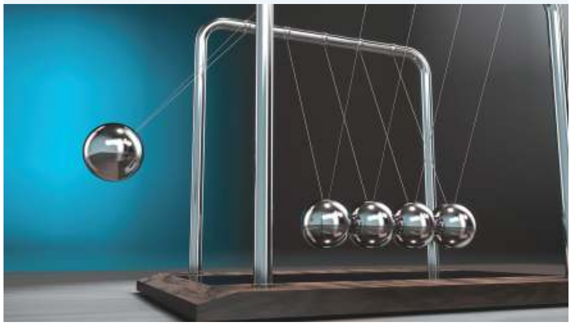
Conclusion

Write a sentence summarising how energy was transferred and transformed in your machine.

8.4.9 Newton's cradle and pendulum

A **Newton's cradle** (see figure 8.35) is a desk toy that is often seen in offices. It consists of a number of metal balls (usually five) that are suspended by metal threads so that they just touch each other and form a perfectly straight line. When the ball on one end is pulled back and released, it swings down and hits the ball it was next to. The ball on the other end then flies up before coming back down and repeating the process from the other end. All the while, the balls in the middle remain nearly motionless. This sequence repeats itself before gradually dying out. Each ball strike is accompanied by a loud 'clacking' sound.

FIGURE 8.35 In a Newton's cradle, the outside balls swing backwards and forwards while the middle ones stay almost still.



When it is working, Newton's cradle demonstrates the transformation and transfer of energy as follows:

- When everything is still, there is no kinetic energy in the system because nothing is moving. Also, because the balls are at their lowest points there is no gravitational potential energy.
- When the first ball is lifted up to its release height, it now has gravitational potential energy due to this height.
- When the ball is released, it swings down, loses height and picks up speed. It loses gravitational potential energy and gains kinetic energy.
- At the bottom of its swing, just before it hits the next ball, all its gravitational potential energy has been converted into kinetic energy.
- When it hits the next ball, it stops and therefore has no kinetic energy. The kinetic energy has been passed to the next ball. As this ball cannot move without hitting a third ball, the kinetic energy is transferred on to the third ball without the second ball moving anywhere. This process is repeated until the kinetic energy reaches the last ball in the line.
- This last ball then swings up with the same speed as the first ball and reaches the same height before falling and repeating the whole process in the opposite direction.

In theory, a Newton's cradle should continue moving for a very long time. However, during every energy transfer there will always be some loss of useful energy. In this case, sound energy is produced when the balls collide with each other, the sound energy is non-useful and is lost to the Newton's cradle. This means that the amount of energy available for each transfer gets smaller and smaller until everything stops because there is no energy left.

A pendulum is a Newton's cradle with only one ball. The mass on the end of a string or wire behaves in the same way as the balls in a Newton's cradle.

When the mass is lifted, it gains gravitational potential energy. This gravitational potential energy is transformed into kinetic energy as the mass falls. At the lowest point, the mass no longer has any gravitational potential energy; it only has kinetic energy and is moving at its fastest speed. As the mass begins rising again, the kinetic energy is transformed back into gravitational potential energy until it reaches its highest point when it no longer has any kinetic energy and only has gravitational potential energy. Some energy is transformed into heat due to friction between the mass and the air while the mass moves.

This process will repeat itself over and over again until too much energy has been transformed into heat and the pendulum no longer has enough energy to keep moving.

INVESTIGATION 8.5

Energy transformations in a pendulum

Aim

To investigate the behaviour and energy changes in a pendulum

Materials

Laboratory version

- retort stand (as tall as possible)
- boss head and clamp
- string
- object to attach to the string
- book or similar object to mark release height
- timing device

Outdoors 'mega' version

- rope
- heavy object (e.g. concrete block)
- tree branch or beam to tie rope over
- object to mark the release height
- timing device

Method

1. Tie one end of the string or rope to the object that will be the weight at the end of your pendulum.
2. Tie the other end to the clamp or beam that will be the top of your pendulum. Make sure that both ends are tied securely.
3. Pull the weight back to a certain height while keeping the string or rope taut.
4. You now need a marker for this height. If inside, you could place a book just behind the pendulum at this point. If outside, you could just use your hand to mark this point, being careful to keep it still.
5. Release the pendulum (do not push it) and make sure it swings freely without hitting anything (including yourself!).
6. Observe what happens each time the pendulum returns to its starting position. Time how long it takes for each complete swing (this is called the **period**).
7. Repeat steps 3–6 using different starting heights.

Results

1. Describe the pattern that occurs each time the pendulum swings back to its starting position.
2. Do different starting heights affect this pattern?
3. Draw up a table to record the different starting heights you used, and the period obtained in each case.

Discussion

1. Do different starting heights affect the period?
2. The energy contained in your pendulum is distributed between gravitational potential energy (E_g) and kinetic energy (E_K). Describe the energy changes that occur during each complete swing of your pendulum.
3. Does your answer to question 2 account for all the energy transformations involved? Support your answer with observations from your experiment.
4. A child's swing is an example of a pendulum. In energy terms, explain why a child can start from rest and make the swing go higher with each swing.
5. Years ago, many clocks had a pendulum mechanism to help them keep accurate time. The pendulum was able to keep swinging backwards and forwards for a considerable period of time without dying out. Find out why this was possible and explain your answer in terms of energy.

Conclusion

Summarise your findings from the investigation about the total energy in a pendulum and the forms in which it is presented.

8.4.10 Catapults

A catapult was commonly used in the past, both for hunting and during battles. By using a small catapult, a hunter could throw a stone further than by just using their hands, which helped the hunter stun an animal before the animal could run away. Large catapults allowed armies to throw large rocks and other heavy items at or over the walls of castles or cities. These catapults could destroy walls to allow foot soldiers to enter a city or destroy buildings within the city, causing chaos and making the city easier to invade. Whatever the size of a catapult, they all work in the same way.

- An object is stretched to make it store elastic potential energy. In a small catapult, this is a piece of elastic or animal hide. In a large catapult this is normally the wooden arm of the catapult itself. (Kinetic energy from moving the object is transformed into elastic potential energy stored inside the object.)
- When the catapult is released, the stored elastic potential energy is given to the rock or stone so that it can fly through the air to its target. (Elastic potential energy in the catapult is transformed into kinetic energy as the catapult arm moves. This kinetic energy is transferred to the rock or stone, making it move.)

FIGURE 8.36 A large catapult used by ancient armies when attacking walled cities and opposing armies.

FIGURE 8.37 A small catapult, also called a slingshot, used by hunters to attack animals by stealth.

8.4.11 Water wheels

Water wheels have been used to provide energy to large machines and factories for centuries. They were the first 'power stations'. Water wheels were built on the banks of fast running rivers or under waterfalls and used the moving water to make the wheel turn. Water wheels were then connected to grinding stones used to turn wheat and other grains into flour or to early automated machines in the factories, turning cotton into cloth. Water wheels were also connected to generators to generate small amounts of electricity for large farms, and for factories during the Industrial Revolution.

The energy transfers and transformations connected to water wheels consist of the following:

- The moving water makes the water wheel turn. (Kinetic energy from the water transfers to the water wheel, giving it kinetic energy.)
- The water wheel axle is connected to pulley systems, gears and levers that make a range of machines function, including grinding stones creating flour in mills. (The kinetic energy of the water wheel is transferred to the axle, a long rod running through the middle of the water wheel, which then transfers kinetic energy to other machines)

FIGURE 8.38 A traditional water wheel turned by running water passing below the wheel

FIGURE 8.39 A second type of water wheel turned by water falling on the wheel from above. This type of water wheel could also be built under a waterfall.

ACTIVITY: The use of a waterwheel

Waterwheels have been used in the past (and are still being used) to convert the energy of moving water to other useful forms of energy. Research and report on one example of the use of a waterwheel. In your report, use flow diagrams to illustrate the transformations and transfers of energy that take place.

8.4.12 Car accidents

In car accidents, the energy of the moving car is transferred to whatever the car hits and is also used to help prevent injuries to the people inside the car. Some energy is also transformed into heat and sound. The faster a car is moving just before the crash, the more energy is involved in the car crash, making damage and injuries more likely. This is why many roads around schools and homes have a lower speed limit.

- The moving car hits another car, a person or a tree, making that object move. (Some of the kinetic energy of the car is transferred to the other car, person or tree.)
- The car is squashed or dented during the accident and the air bags are activated. (The remaining kinetic energy of the car is transformed into elastic potential energy as the car is squashed, and electrical energy, making the air bag inflate.)

FIGURE 8.40 After a car accident, the cars involved in the accident have been dented due to kinetic energy being transformed into elastic potential energy. The cars have also moved away from the original crash site due to the transfer of kinetic energy.

DISCUSSION

Cars travelling at high speeds are more likely to cause damage and injury if they have an accident. This is because fast cars have more kinetic energy, which needs to be transferred to other objects or transformed into different types of energy during an accident. Speed limits are one way to prevent serious car accidents happening.

What is the speed limit outside your school? On the street you live on?

What do you think the speed limit should be on different roads?

What are some other ways to encourage drivers to slow down when on the roads near your school?

SCIENCE AS A HUMAN ENDEAVOUR: Nikola Tesla and Swami Vivekananda

How could two people, with very different world views, collaborate to explore the relationship between mass and energy?

In 1896, a meeting between Nikola Tesla — an engineer and physicist — and Swami Vivekananda — a monk, religious teacher, author and philosopher — saw them exploring the relationship between mass, energy and the elementary concepts of the Vedantic doctrine, which include:

- Prana (energy)
- Akasha (matter)
- Dyuloka (electric sphere), where Prana and Akasha existed as one.

Based on their conversation, Tesla set about trying to prove mathematically the equivalence of mass and energy; however, he was unsuccessful because he believed that mass might be converted into energy.

It wasn't until 1905 that Albert Einstein published the formula $E = mc^2$, where he proved that energy and mass are the same thing, just in different forms.

FIGURE 8.41 Nikola Tesla

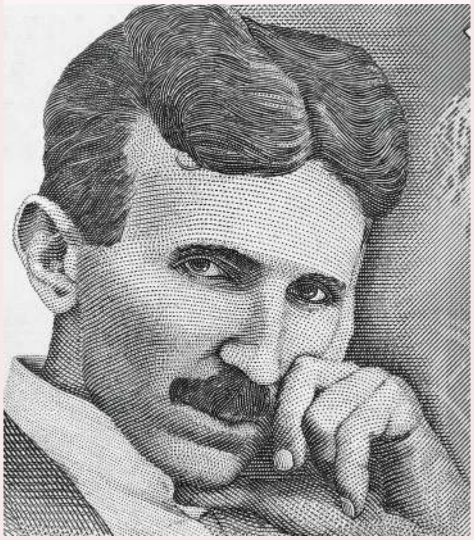


FIGURE 8.42 Swami Vivekananda

1. What were the main ideas that Swami Vivekananda shared with Nikola Tesla?
2. How did Tesla and Vivekananda's conversation inspire Tesla's work?
3. Who eventually proved the relationship between mass and energy, and what was the formula?
4. Why is it helpful for scientists to talk to people with different ideas and views?
5. How has Einstein's formula $E = mc^2$ helped the world today?

Multidisciplinary endeavours to advance scientific knowledge make use of people's different perspectives and worldviews (VC2S8H02)

SCIENCE AS A HUMAN ENDEAVOUR: Newton, Einstein and gravity

We are all familiar with the effects of gravity. We know that it causes objects to fall. We know that it keeps us 'fixed' to the surface of Earth. We know that spacecraft have to travel fast enough to overcome its pull if they are to reach orbit. We now know that the same force that we are familiar with here on Earth's surface is also responsible for the motions of planets, stars and entire galaxies.

Although we take it for granted, gravity is one of the most important forces in nature. Although its effects have long been observed, it took the work of two men — Sir Isaac Newton and Albert Einstein — to describe it and unravel its consequences. In science, theories have to not only explain current observations, but also need to predict new observations that can be tested by experiments. Newton's and Einstein's theories enabled this to be done. People's knowledge and understanding of gravity was therefore moved from just a descriptive basis to a true scientific basis.

Sir Isaac Newton

Sir Isaac Newton is regarded as probably the most influential figure in Western science.

Newton was born in England in 1642 and died in 1727. During his lifetime, he was responsible for many discoveries, inventions and theories. These included the following.

- The invention of the first reflecting telescope: Reflecting telescopes use mirrors and a relatively small lens. Prior to this, telescopes relied on arrangements of lenses to gather and focus light. Today, virtually all astronomical telescopes are reflectors, whereas nearly all terrestrial telescopes use lenses.
- The discovery that white light could be broken into the colours of the rainbow by a prism: From this and further work, he put forward a new theory that light was composed of tiny particles.
- The invention of a simple form of calculus: This was an entirely new branch of mathematics.
- The discovery that motion could be explained and described by the action of forces: The laws that he put forward have since come to be known as Newton's first, second and third laws of motion.
- His theory of universal gravitation.

A popular story is that Newton 'discovered' gravity when he saw an apple fall from a tree. We don't know if this is true, but we do know that he was forced into long-term isolation by the Great Plague of London in 1665. (A bit like our lockdowns in recent times due to the COVID-19 pandemic!) This gave him plenty of uninterrupted time to imagine and think, which allowed him to develop his theory that the gravity experienced on Earth was the same force that operated throughout the universe.

The essential features of this theory are as follows:

- Gravity is an attractive force between objects and is due to their mass. (All objects will therefore attract each other.)
- Gravity is a very weak force, but is due to the amount of mass an object has. (This means that its effects are really only noticed when objects have a very large mass; for example, planets stars and moons.)
- The strength of gravitational attraction increases as objects get closer together, and vice versa. The amount of this change is predicted by the 'inverse square law'. For example, if two objects halve the distance between them, gravity will be four times stronger; if they double their distance apart, it will be four times weaker.

After Newton, much of the physical world could now be described with great mathematical accuracy. In 1846, for example, the planet Neptune was discovered. It had been earlier observed that the orbit of the planet Uranus seemed to be affected by something further out in the solar system. Newton's laws were used to predict where this new planet would be, thus leading to Neptune's discovery.

Newton's laws are still used today and give accurate results in most situations. However, science is an ever-changing subject and is always being influenced by new observations and ideas. In situations where gravity is very strong, it has been observed that these laws do not always apply as expected. It took until the early twentieth century for another great scientist, Albert Einstein, to figure out why.

Albert Einstein

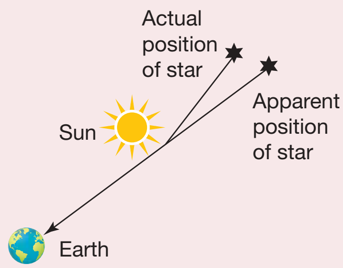
Born in Germany in 1879, Albert Einstein is also regarded as one of the most influential scientists of all time.

In 1905, Einstein published three papers that immediately established his reputation as a brilliant scientist.

- The first of these provided mathematical proof for the existence of molecules.
- The second concerned itself with something called the 'photoelectric effect'. This led to the invention of many devices that are important and familiar today, including transistors, photoelectric cells, computers, electron microscopes and LEDs, to name just a few. Einstein was awarded a Nobel Prize for this paper in 1921.
- The third introduced Einstein's famous 'special theory of relativity'. This paper dealt with the motion of objects relative to each other, especially when they were travelling at close to the speed of light. It also said that nothing can travel faster than the speed of light (300 000 km per second).

Following this, Einstein spent a number of years working on a broader theory of relativity by incorporating gravity into it. By 1916, he was ready to publish this work, which has since become known as the 'general theory of relativity'. This theory was not only able to incorporate Newton's ideas about gravity, but was also able to correct certain problems that had been discovered in them. A new way of looking at gravity was born.

FIGURE 8.43 Einstein correctly predicted how light would be bent as it passes the Sun.



One of the predictions from the general theory of relativity was that light could be bent in a certain predictable amount when it passes a massive object. Einstein predicted that the position of a star just behind the Sun would appear to shift a little as its light passed the massive Sun. Normally, of course, this would not be noticeable because of the Sun's brightness. However, during a complete solar eclipse, it should be noticed. In 1919, such an eclipse occurred and scientists were able to verify Einstein's predictions.

In 1933, Einstein moved to the United States to avoid being in Germany during the rise of Adolf Hitler. In his lifetime, he held German, Swiss and American citizenships. At the time of his death in 1955, he was working on a way to bring together many important scientific theories into one 'supertheory', a quest that continues to this day.

What inspired Einstein to think about gravity?

Scientists were aware of a number of things that could not be explained by Newton's ideas of gravity. One example was the irregularities in the orbit of the planet Mercury. Mercury is the smallest planet in our solar system and is the closest to the Sun. It was even thought for a while that there must be another planet even closer to the Sun pulling on Mercury and affecting its orbit. This proposed planet would have been almost invisible due to the Sun's brightness. Einstein questioned this, and his general theory of relativity was able to explain the irregularities in Mercury's orbit.

Einstein also questioned why light must travel in straight lines. He was able to explain why light might sometimes appear to travel in a curved path, especially when viewed from different viewpoints, and also when passing close to massive objects with strong gravity.

Another question that worried Einstein was how gravity actually worked. He wanted to explain its workings, rather than just describe them as Newton had done. This led him to predict the existence of gravity waves. These were only discovered in 2015.

1. What was Newton's main idea about gravity?
2. Why was Einstein's theory of relativity needed if Newton's laws worked so well?
3. How was Einstein's prediction about the bending of light tested?
4. What does the discovery of gravitational waves in 2015 tell us about Einstein's predictions?
5. What does the development of Newton's and Einstein's theories show about how scientific ideas change over time?

Scientific knowledge, including models and theories, can change because of new evidence (VC2S8H01)

INVESTIGATION 8.6

Energy transformations in a bouncing ball

Aim

To observe energy transformations in a simple system and identify where energy is 'lost'

Materials

- elastic band
- electric fan
- small coin or other mass
- electric lamp
- solar cell and motor
- electric torch
- yo-yo
- wind-up toy
- eraser
- ruler
- high-bounce ball

Method

Complete each of the following mini experiments, identifying the initial energy type and any other energy types that happen during the activity.

1. Stretch and release the elastic band ten times as quickly as possible. Touch the middle of the elastic band (the part that stretched the most) to see if it has become hotter.
2. Turn the electric fan on, leave it on for 20 seconds and then turn the electric fan off. Touch the central part of the fan to measure the temperature of the fan.
3. Flick the small coin or other mass across a table or bench. Record the way it moves: does it slide along the top of the bench or does it fly above the bench, or both? What happens as the coin comes to a stop?
4. Turn the electric lamp on and shine the light onto the solar cell. Touch the motor and the solar cell to record their temperatures. Explore what happens if the lamp shines on only half or a quarter of the solar cell.
5. Turn the electric torch on and leave it on for 30 seconds before turning it off. Touch the light bulb, or the plastic covering the light bulb, to record the temperature.
6. Use a yo-yo and make it move up and down at least twenty times. Remember to look at the movement of your hand and/or arm when identifying the energies involved in a yo-yo.
7. Set the wind-up toy moving. Explore what happens if you wind it up only a little bit, or a lot.
8. Rub the eraser back and forth over a bench top or table at least 20 times. Touch both the eraser and the bench top to record the temperature.
9. Place a ruler so it is hanging over the edge of a bench. Hit the free end of the ruler. Explore what happens if more or less of the ruler hangs over the edge of the bench.
10. Drop a high-bounce ball from at least 1 m high. Count how many times it bounces and record the change in height of each bounce.

Results

1. Create a table identifying the initial energy, any intermediate energies and the final energy for each of the situations in this investigation.
2. Estimate the relative amount of each type of final energy for each situation. Was there a lot, a little or a medium amount? Include this in your table.

Discussion

1. Draw an energy flow diagram for each situation you investigated. Use your results table to help you do this.
2. Identify the situation that had the most energy transfers. Describe these transfers.
3. Identify the situation that had the most energy transformations. Describe these transformations.
4. Explain the importance of touching some of the objects to measure their temperature. Give a more accurate way to detect any thermal energy.
5. If a basketball was used in the investigation, predict the number of bounces and the change in height of each bounce. Would it be more or less than you observed with the high-bounce ball?

Conclusion

Write a conclusion describing the difference between an energy transfer and an energy transformation. Use examples from the situations in this investigation.

8.4 Activities

learnon

8.4 Quick quiz on	8.4 Exercise

Select your pathway

■ LEVEL 1	■ LEVEL 2	■ LEVEL 3
1, 2, 3, 5, 7, 8	4, 6, 9, 10, 12, 13, 14, 21	11, 15, 16, 17, 18, 19, 20

Remember and understand

1. Complete the table, listing the useful energy and the wasted energy converted by each of the devices.

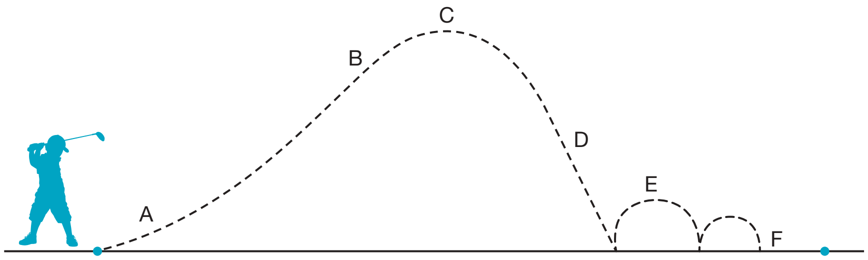
Device	Source of energy	Form of useful energy	Forms of energy wasted
A torch			
A wind-up toy			
A pop-up toaster			
A gas cooktop			
A car engine			

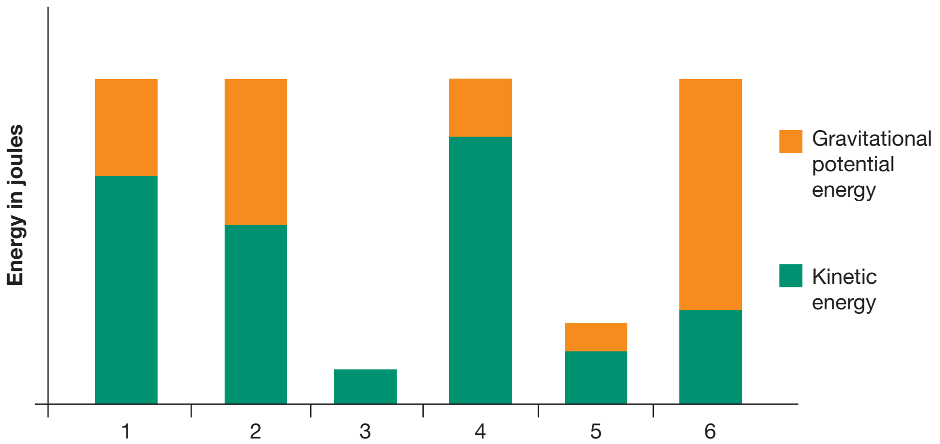
2. A friend tells you that a light globe transforms 60 J of electric potential energy into 100 J of light. Are they correct? **Justify** your response.
3. When a person kicks a soccer ball, energy from their body is given to the soccer ball. **State** which two useful forms of energy the soccer ball gains as a result.
4. When playing squash, a very compressible ball that does not bounce very much gets warm. **Name** what types of energy are involved just before and just after the ball is hit.
5. During exercise, kinetic energy is generated by your muscles. **State** what other type of energy is also generated.
6. **Identify** four types of energy that are present during an explosion.
7. A billiard ball strikes another ball exactly head-on and stops completely. **State** where all its energy has gone.

Apply and analyse

8. **Outline** at least three reasons efficiency is important for devices that use fossil fuels.
9. If a stretched rubber band has 12 J of elastic potential energy, and 9 J of kinetic energy is produced when the band is released:
   a. **explain** what has happened to the 'lost' 3 J of energy
   b. draw a fully labelled Sankey diagram of this situation.
10. An object is dropped from a height of 20 m. At a point during its fall towards the ground, it has 15 J of gravitational potential energy and 5 J of kinetic energy.
    a. **Identify** whether the ball is closer to the ground or closer to the drop height of 20 m. **Justify** your answer.
    b. Draw an energy flow diagram for the energy transformations happening as the ball falls.
    c. Draw a Sankey diagram of the ball's fall. Label the types of input and output energy, including any non-useful energy. You do not need to provide any numbers on your diagram, but make sure the width of each arrow shows the amount of each type of output energy.
11. When a tennis ball is bounced on the ground, it never returns to its original height.
    a. **Explain** why this happens.
    b. Draw an energy flow diagram for the ball falling, touching the ground and then rising upwards during the first bounce.
    c. The ball bounces for a second time. **Predict** whether the ball will lose the same amount of height as it did on the first bounce. **Justify** your answer.
12. **Discuss** two ways that you could hit a ball further.
13. **Explain** why it is safe to stand right behind a swing that is swinging if you do not push it, but why it might be dangerous to you if you do push it.

14. SI Rubber bands store energy as elastic potential energy when they are stretched. **State** two hypotheses that you could test experimentally concerning the amount of energy stored in a stretched rubber band.
15. Using oil is very important in a car engine, even though it is not used as a fuel. **Explain** the purpose of the oil.
16. SI The following bar graph shows not only the total energy involved, but also the proportions of kinetic energy and gravitational potential energy when a golf ball is hit into the air before rolling down the fairway and coming to rest. Match each bar to the correct position of the ball during its flight.





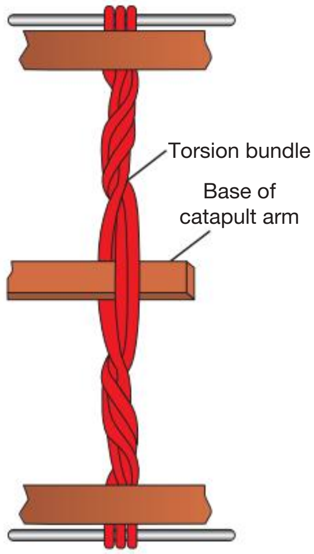
Evaluate and create

17. Prepare a poster that demonstrates the energy changes that take place during a bungee jump. Start from the moment the person leaves the platform until they are lowered back to the ground.
18. SI Design an experiment to investigate what happens in a Newton's cradle if:
    a. two balls are released to start it instead of one
    b. an even number of balls are present.
    Write up your experiment in the usual way. Make sure you report on the energy changes involved in your discussion. Are you able to make any conclusions about the amount of energy involved in the collisions?
19. The energy we get from eating a piece of fruit starts from the Sun! **Describe** the energy transformations involved in this process using a flow diagram.
20. SI Create a poster-sized flow diagram to show the energy transformations that take place to produce lightning and thunder. (Think first about how the clouds become electrically charged during an electrical storm.)
21. A catapult like the one in figure 8.44 was used by the Romans more than 2000 years ago to attack castles, cities and invading armies. The long arm was held in its usual vertical position with rope twisted around its base in what is known as a torsion bundle (figure 8.45). The arm was pulled back towards the ground using a second rope so that the bucket could be loaded with a missile. This caused the torsion bundle to twist more tightly. When the arm was released, the torsion bundle quickly untwisted and it returned to its vertical position, releasing the missile from the bucket at high speed towards the target. The missiles fired included rocks, burning tar and even human corpses. Use flow diagrams to show:
    a. the energy transfers that took place during the loading and firing of the missile

b. the energy transformations that took place from the time that the missile was loaded until the time that the missile found its target.

FIGURE 8.44 A Roman catapult

FIGURE 8.45 The torsion bundle



Answers and sample responses are available in your digital formats.

LESSON 8.5 Review

8.5 Success criteria

Tick the column to indicate that you have completed the lesson and how well you think you have understood it using the traffic light system.

(**Green:** I understand; **Yellow:** I can do it with help; **Red:** I do not understand)

Lesson	Success criteria	Green	Yellow	Red
8.2	I can describe the different forms that energy can take, and be able to classify them as potential energy or kinetic energy.			
8.3	I can describe the different ways that thermal energy is transferred in solids, liquids and gases, using particle models to explain conduction, convection and radiation.			
8.4	I understand how energy is transformed from one form to another in simple systems.			
	I can identify energy that is not useful.			
	I can analyse systems for energy efficiency using flow and Sankey diagrams.			

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Post-test	Topic 8 Post-test
eWorkbook	Topic 8 eWorkbook
Digital document	Key terms glossary

8.5 Activities

learnon

8.5 Review questions

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 5, 6, 9	3, 7, 10, 13, 16	4, 8, 11, 12, 14, 15

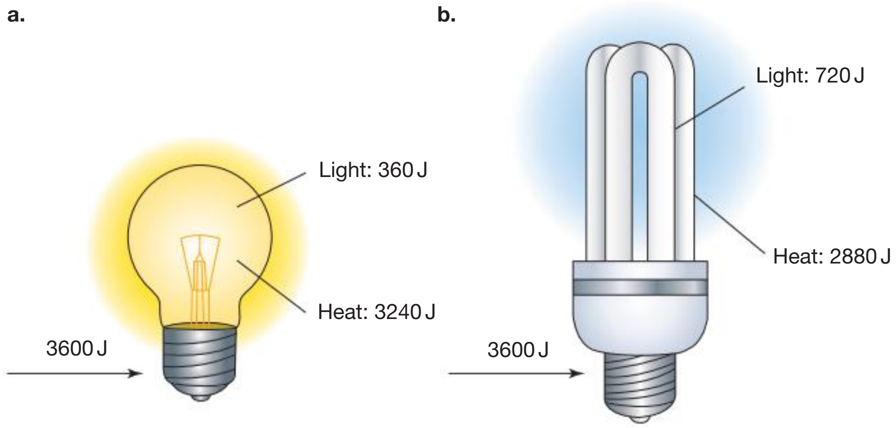
Remember and understand

1. Replace each of the following descriptions with a single word.
   a. Energy associated with all moving objects
   b. Energy associated with the position of an object
   c. The form of energy that causes an object to have a high temperature
   d. The form of energy stored in a battery that is not connected to anything
   e. The source of most of Earth's light

2. Give an example of an object that has:
   a. elastic potential energy
   b. gravitational potential energy.
3. What is conduction? **Name** one everyday example.
4. **Explain** why elastic potential energy is present in a working Newton's cradle.
5. **Explain** why thermal energy is a form of kinetic energy.
6. MC When Aboriginal and Torres Strait Islander Peoples start a fire using traditional methods,
   A. friction converts kinetic energy into thermal energy.
   B. chemical energy in tinder is converted into thermal energy.
   C. chemical energy in tinder is converted into light energy.
   D. all of the above statements are true.
7. MC Which method of heat transfer can occur in the vacuum of space?
   A. Conduction
   B. Convection
   C. Radiation
   D. Friction

Apply and analyse

8. **Compare** the efficiency of the two light bulbs shown below.

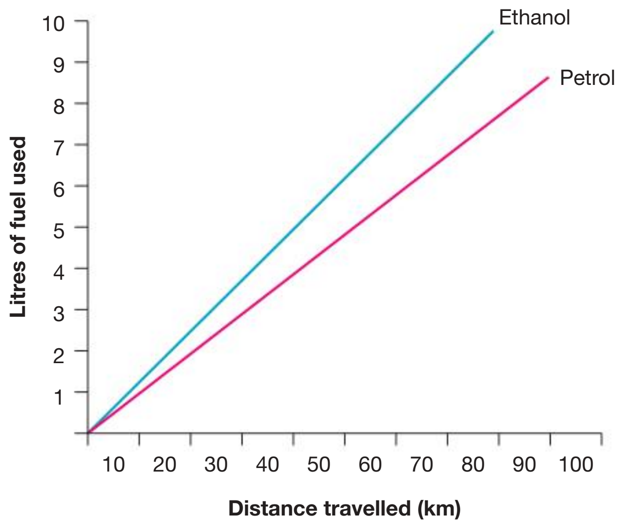


9. When a kettle of water is boiled on a gas cooktop, not all of the energy stored in the gas is used to heat the water. **State** where the rest of the energy goes.
10. **Explain** why metal cooking pans often have plastic or wooden handles.
11. **Explain** why it is not possible for an energy converter such as a battery or car to have an efficiency of 100 per cent.
12. **Explain** why electrical energy can be both a form of kinetic energy and a form of potential energy.
13. High jumpers train to develop both their muscles and their technique. **Explain** why, in terms of energy, this enables them to jump greater heights.

Evaluate and create

14. Draw a flow diagram to illustrate the energy transformations that take place:
    a. after you switch on a torch
    b. when a firecracker is lit
    c. when a ball rolls down a hill and then up another hill.

15. You are to design a lunchbox that minimises heat transfer. Which materials would you use and why?
16. The graph shows the fuel consumed versus distance travelled for two cars. These cars are identical except for the fact that one is fuelled by ethanol and the other by petrol. What does this graph tell you about the amount of chemical potential energy stored in each litre of each fuel?



Answers and sample responses are available in your digital formats.

To test your understanding and knowledge of this topic, go to your learnON title at www.jacplus.com.au and complete the **post-test**.

9 Energy efficiency at home

CONTENT DESCRIPTION

Household energy consumption can be analysed using an energy audit and is affected by appliance choice, building design, season and climate (VC2S8U16)

Source: Victorian Curriculum F–10 Version 2.0

LESSON SEQUENCE

LESSON 9.1 Overview

9.1.1 Introduction

Most Australians spend an overwhelming amount of time in residential dwellings. In the latest Australian Time Use Survey, respondents were asked how much time they spent at home. The average was over 17 hours per weekday and nearly 18.5 hours per day on the weekend!

With so much of your time spent in one place, it makes sense to consider the impact: on your wellbeing, on the broader community and on the natural and built environments.

FIGURE 9.1 An energy efficient home creates a comfortable environment for studying, working and creating.

Constructing and maintaining a building consumes substantial amounts of resources. Home owners have a strong self-interest in reducing unnecessary use of materials or energy. Ethical and economic considerations, and a desire to minimise waste and greenhouse gas emissions, are powerful motivators to use less, while doing more with what we use. There are many good reasons to find a balance between our homes being as efficient, and as affordable, as possible.

Efficiency is about achieving more while using fewer resources. For example, replacing an old electric water heater with a modern heat pump system can cut the household energy used to heat water by up to 60 per cent. This change significantly lowers both electricity bills and carbon emissions.

In real-world processes, efficiency ranges from 0 to 100 per cent. Obstacles such as friction in mechanical systems or electrical resistance in circuits can lead to losses, transforming useful energy into heat or sound. Understanding these challenges helps in designing homes that are efficient and sustainable.

Houses are complex structures requiring a variety of inputs for construction, including specialist tradespeople, manual labour, vehicles and fuel, timber, metal, stone, bricks and large amounts of kinetic and potential energy. Beyond construction, homes rely on broader infrastructure such as roads, water, electricity and gas networks.

Once construction is complete, living in and maintaining the dwelling involves new inputs such as water, electricity and gas. Repairs and upgrades are necessary over time, and efficiency becomes an ongoing consideration.

This topic will focus on how a building can better respond to its location and climate, and how design choices and decisions about materials and appliances contribute to its overall efficiency. One way that you can better understand (and perhaps seek to improve) the efficiency of your own home is to conduct a home energy audit.

DISCUSSION

1. Why does a one-size-fits-all, highly efficient home design not work in every setting?
2. Why are timber frames still used in houses, rather than modern materials such as steel?
3. How does insulation in the walls of a house help it stay cool in summer and warm in winter?
4. A house with solar panels needs a battery to make efficient use of the energy they generate. Why?
5. Not every home incorporates the most efficient materials and appliances. Why is this?
6. How many different resources went into making the walls/floor/roof of the building you are in?
7. How does your home's design affect its energy efficiency? What changes could be made to improve it?
8. What are the environmental impacts of using hardwood versus softwood in home construction?
9. How can modern technology, such as smart meters and automated home systems, help improve energy efficiency?

SCIENCE INQUIRY: Inputs, outputs and efficiency

The concept of efficiency is best understood as a measure of how effectively a process turns its inputs (such as materials or energy) into useful outputs. Efficiency is a ratio: it expresses how much of the input has been converted into a useful output. For this reason, it can be expressed as a percentage. A higher efficiency is better, as it indicates that the process is less wasteful.

Thousands of years ago, the Roman Empire constructed stone aqueducts that allowed water to flow to farms and cities. This would be an inefficient approach in the warmer parts of Australia, due to the large amount of evaporation that would occur. The output would be significantly smaller than the input. Today, engineers have the option of using systems of pumps and enclosed pipes to more efficiently transfer large volumes of water.

FIGURE 9.2 Evaporation from uncovered aqueducts reduced their efficiency.

1. What are some real-world examples where improving efficiency has led to significant energy savings?
2. How do modern systems for transporting water and electricity improve efficiency compared to historical methods?
3. What factors can decrease the efficiency of an energy system, and how can they be mitigated?
4. How does efficiency impact sustainability and resource conservation?
5. How can households apply efficiency principles to reduce energy and water waste?

Information and processed data can be analysed to show patterns, trends and relationships, and to identify anomalies (VC2S8I05)

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Pre-test	Topic 9 Pre-test
eWorkbooks	Topic 9 eWorkbook Student learning matrix
Practical investigation eLogbook	Topic 9 Practical investigation eLogbook
Digital document	Key terms glossary

LESSON 9.2 Sustainable homes

LEARNING INTENTION

In this lesson you will:
- distinguish between renewable and non-renewable resources
- evaluate the sustainable use of different resources
- compare the benefits and risks of resource extraction and energy production.

9.2.1 Sustainability matters

No matter where you live — on a farm, in an inner-city suburb or a regional town — sustainability is becoming increasingly important.

FIGURE 9.3 The resilience of Australian ecosystems is being tested by extreme weather events.

Greenhouse gas emissions due to human activity have already caused a noticeable rise in the average temperature of Earth's atmosphere and hydrosphere (oceans, rivers, lakes, etc). The resulting melting of glaciers and polar ice caps is one factor contributing to rising sea levels. With increased thermal energy in the atmosphere comes the risk of more turbulent, extreme and unpredictable weather.

The global human population has grown to record numbers and continues to grow. At the same time, improving living standards mean that people have come to expect more (and better quality) food, clothing and technological devices. We set ever-higher standards for our vehicles, roads, communication networks, holidays and leisure activities. Those demands come at a real cost in materials and energy.

Building more sustainable homes that use fewer resources while producing less waste and reducing emissions is a great way to address several of these global problems simultaneously.

CASE STUDY: Plan Melbourne 2017–2050

Outlining a vision for the future of our capital city, the ***Plan Melbourne 2017–2050*** framework sets ambitious goals for creating a sustainable urban environment. The framework expects that:

'The Melbourne of 2050 needs to have become a low-carbon city designed to cope with the effects of climate change … Buildings will be designed to improve energy efficiency, collect and reuse water and to generate energy from local renewable sources[.]'

The framework highlights the importance of integrating sustainability into urban planning. It reflects broader global trends aimed at mitigating climate change and preserving natural resources. By adopting these measures, Melbourne could reduce greenhouse gas emissions and improve resilience against environmental challenges such as extreme weather and resource scarcity.

SCIENCE AS A HUMAN ENDEAVOUR: The idea of 'home'

What do you think of when you hear the word 'home'? It might be a physical location or building, your local community or the environment around you. For some Australians, 'home' is a mobile concept, with caravans and campervans providing comfortable accommodation while they travel around the country.

FIGURE 9.4 Home could just be a caravan and wherever you are planning to stay the night.

Archaeological discoveries in the Melbourne and Sydney regions provide evidence of human activity throughout the past 50 000 years, but that did not include clearing the land to build cities. In many parts of Australia, seasonal movement between different sites was the most effective way to make use of natural resources (including plants and animals, water and stone). Shelter from the elements may have been temporary, portable or adapted from naturally occurring sites (such as the rock shelters used by the ancestors of the Taungurung).

The UNESCO World Heritage site at Budj Bim is a significant example of the pre-colonial built environment, constructed from volcanic stone and used for over six thousand years prior to European settlement. By channelling waterways to trap and farm eels, the Gunditjmara Peoples ensured a reliable source of food and trade goods that sustained their people for millennia.

1. What does the concept of 'home' mean to you? Conduct a brainstorming session with your classmates or discuss and compare your own definitions.
2. How do you think the creation of your home has impacted the natural environment? How does this compare to the ways in which the Taungurung, Gunditjmara and other traditional owners of this land occupied and altered the landscape?

Multidisciplinary endeavours to advance scientific knowledge make use of people's different perspectives and worldviews (VC2S8H02)

9.2.2 Renewable and non-renewable resources

Resources used to build and maintain homes can broadly be classified into two categories: **renewable resources** and **non-renewable**.

How a material is classified is different from whether it is **abundant** or not.

FIGURE 9.5 Sand is abundant in Australia, but mining it impacts local ecosystems and affects resource sustainability.

SAMPLE PROBLEM 1: Renewable or non-renewable?

Classify each of these materials as renewable or non-renewable.

a. Sand (one ingredient of concrete)
b. Water (another ingredient in concrete)
c. Copper (for use in electrical wiring)
d. Bamboo (to produce floor panels)

THINK	WRITE
a. Sand is created very slowly, as the water cycle breaks down larger rocks into ever-smaller pieces.	**a.** Sand is a non-renewable resource.
b. The water cycle replenishes streams, rivers and lakes 'rapidly' (over a period of months or years).	**b.** Water is a renewable resource.
c. Copper is obtained by mining minerals such as chalcopyrite. There is a large but finite supply.	**c.** Copper is a non-renewable resource.
d. With the right growing conditions, bamboo can be grown rapidly and replanted after harvesting.	**d.** Bamboo is a renewable resource.

PRACTICE PROBLEM

Classify each of these materials as renewable or non-renewable.

a. Hardwood lumber harvested and machined from old-growth forest timber (such as posts to support a deck)
b. Sustainably harvested woodchips (glued to make composite wall panels)
c. Iron (smelted with carbon to produce steel beams)
d. Clay (baked into bricks)

Moving from non-renewable to renewable

Many non-renewable resources, such as coal and iron ore, have historically been abundant and easy to extract. However, if people continue to rely heavily on these resources, there will come a time when all readily accessible sources are depleted. Even if more of a resource exists in less accessible areas, such as deep underground or in untouched wilderness, exploiting these sources can become ethically and economically undesirable.

For home builders, materials may become increasingly unaffordable as the supply dries up. It would be ideal to source all building materials from renewable sources. This would ensure a consistent future supply and prevent the need for continuous expansion into new areas to extract raw materials.

Actions can be taken to maintain or increase the availability of resources. For example, rare earth metals can be recovered by collecting and disassembling obsolete mobile phones, reducing the need to mine new minerals. Similarly, when demolishing older buildings, useful fittings and features can be salvaged, and even the rubble can be sorted to extract reusable materials such as steel.

Some materials, such as timber, can be sourced in ways that make them more or less renewable. Sustainable timber is usually grown on plantations, with new trees planted to replace those that are harvested. In contrast, removing timber from **old-growth forests** impacts the ecosystem's health, as even dead trees and fallen branches provide food, shelter and nesting sites for many native species. If too much timber is removed from a forest, the ecosystem may fail to recover.

FIGURE 9.6 a. Commercial logging of old-growth forests is no longer allowed across most of Australia.
b. Plantations are harvested instead, those trees grown specifically for that purpose.

EXTENSION: Crude oil

Crude oil is a mix of hydrocarbons used to make fossil fuels, such as petrol, diesel and jet fuel, as well as raw materials for many plastics and synthetic materials. Extracting crude oil takes energy, and the deeper the drilling, the more energy it takes. As an oil reservoir gets used up, other materials might be pumped underground to push the remaining oil to the surface, which uses even more energy.

At some point, the energy needed to extract one barrel of crude oil might be equal to the energy obtained from that barrel. This means it might not be worth the cost to keep extracting oil. People might use renewable energy sources to keep getting oil for making plastics and high-performance fuels, but these will likely become more expensive in the future.

ACTIVITY: Benefits and risks

Many different factors need to be considered when sourcing building materials — it is not automatically the case that reusing materials (or sourcing them from a renewable source) is the best option.

List some possible benefits and risks in each of the scenarios below.

- **Is it ethical to interfere with a natural environment for convenience and safety?** Selectively removing dead timber from old-growth forests (including via the practice of cultural burning) may change the frequency and severity of bushfires. Some of this timber could be used in building homes.
- **Should mining sand in developing countries continue while preserving Australian beaches?** The fine white sand produced from coral reefs is an excellent building material. Many of the world's most popular tourist beaches feature this kind of sand, but it is in short supply.
- **Can pursuing efficiency in construction be justified if it comes at an environmental and social cost?** In theory, fresh water is a renewable resource. That doesn't mean it is abundant. Large volumes of water are used when mixing concrete, and to prevent it cracking while drying. Using concrete slabs rather than bricks means larger structures can be built faster.

Extension: These scenarios could be further developed into arguments ('for' and 'against') allowing you to run a class debate.

9.2.3 Carbon costs

One reason to consider the energy efficiency of a home is that producing energy often comes with a hidden cost. Significant amounts of **carbon dioxide** (CO_2) are released into the atmosphere while transporting and processing building materials, and during the production of components with high melting temperatures (such as steel beams and panes of glass). Another major source of emissions is concrete, in all its many forms. Concrete slabs and support pillars release between 50 and 90 per cent of their weight in carbon dioxide as they age.

When these kinds of carbon costs are factored in, many traditional building materials become a less-attractive option for the low-carbon, sustainable homes of the future.

FIGURE 9.7 Structures such as this Melbourne highway overpass contribute to CO_2 emissions as they age.

ACTIVITY: Exploring an energy-generating technology

List some energy-generating technologies you would normally think of as relatively 'green' or renewable, then choose one technology to explore in more depth.

Might that technology actually involve the use of concrete structures, and/or processed materials such as steel, fibreglass, silicon and copper?

Does anything need to be transported to a remote location when setting up a new power-generating facility of that type?

Improving home efficiency limits the amount of CO_2 entering the atmosphere. Scientists are also investigating **carbon sequestration** on larger scales, such as compressing atmospheric CO_2 and storing it in drained oil reservoirs deep underground. Although still being researched, this could provide long-term storage.

Meanwhile, fast-growing green plants naturally capture CO_2 and release oxygen. As plants grow, carbon is stored in their **biomass**, preventing its release into the atmosphere — so long as the material is not burned or decomposed. Bamboo, a rapidly growing grass, may be even more effective than trees as a **carbon sink**.

Additionally, biomass can be reused in materials such as chipboard, MDF and particleboards, reducing waste. Hempcrete, a mixture of plant fibres and a concrete-like material, acts as a carbon sink, strengthens under tension and provides insulation without trapping moisture.

9.2.4 Forest carbon and energy efficiency in home building

Forests play a key role in storing carbon, helping to reduce greenhouse gases in the atmosphere. This has important connections to home building, as the choice of building materials affects both carbon storage and energy efficiency.

When trees grow, they absorb CO_2 from the atmosphere. Some of this carbon stays locked inside the timber even after the tree is harvested and used for construction. This means that timber-framed houses store carbon, making them a more environmentally friendly option compared to materials such as steel or concrete, which release a lot of carbon during production.

A typical single-storey home in Australia uses about 12 m^3 of timber in its frame. While growing, this amount of biomass removes CO_2 from the atmosphere, contributing to reducing emissions. However, the total environmental impact also depends on the energy used to harvest, transport and process the timber.

FIGURE 9.8 A typical single-storey house in Australia uses about 12 m^3 of timber to build the frame.

Softwood versus hardwood in home building

Most new homes in Australia use softwood (such as pine) for their frames, rather than hardwood. This is because:

- softwood trees grow faster, meaning they absorb carbon more quickly and can be replaced more easily
- softwood timber is lighter and easier to transport, reducing fuel consumption and carbon emissions
- processing hardwood requires more energy, leading to higher CO_2 emissions when compared to softwoods such as pine.

The carbon cost of harvesting and processing wood

Hardwood timber, such as eucalyptus, stores more carbon than softwood but is less widely used for a number of reasons.

- *Growth rate:* Hardwoods take decades to mature, while softwoods (such as pine) grow much faster.
- *Density and weight:* Hardwood is denser and heavier, making it more expensive to cut, transport and process.
- *Processing requirements:* Hardwoods need more energy-intensive cutting and drying, increasing CO_2 emissions.

ACTIVITY: Softwood versus hardwood

1. Why do you think softwood (such as pine) is used more often than hardwood in home construction, even though hardwood is stronger? What are the environmental and economic trade-offs?
2. If a timber-framed house helps store carbon, how could homes be designed to maximise carbon storage and reduce overall emissions? What other materials or techniques could help make homes more energy-efficient?

9.2 Activities

learnon

9.2 Quick quiz on	9.2 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 3, 4, 5	2, 6, 8	7, 9, 10

Remember and understand

1. **Name** four building materials that can act as a carbon sink (when made from sustainably harvested biomass).
2. **List** the materials used when producing, transporting, mixing and pouring concrete.
3. Classify mudbricks and MDF (medium density fibreboard) as renewable or non-renewable building materials.

Apply and analyse

4. **Explain** the difference between a material being 'renewable' and it being 'abundant'.
5. Comparing old-growth hardwoods and plantation softwoods, which statement is untrue?
   a. The hardwoods are non-renewable, but the softwoods are renewable.
   b. The hardwoods store more carbon dioxide per cubic metre of timber.
   c. The hardwoods are easier to cut down, cut into logs and transport.
   d. The hardwoods would become less abundant if logging old-growth forests continued.
6. **Suggest** four reasons why a new wind turbine being set up will inevitably involve the emission of carbon dioxide.
7. SI **Identify** ten non-renewable materials used to construct the building(s) at your school. With a classmate, brainstorm whether renewable alternatives exist for any of these materials.

Evaluate and create

8. SI **Outline** what you would include in an ad to persuade homeowners to buy more furniture made from sustainably grown Australian timber.
9. **Describe** four ways in which the glass pane of a window ends up with a carbon cost. For example, transporting the glass from the factory to a warehouse and then to the building site involves combusting fuel, which emits CO_2. **Propose** a method that you expect would help to reduce any one of these factors.
10. SI The frame for a single-storey home uses about 12 m^3 of timber, whereas two-storey homes use about 20 m^3 of timber. It has been suggested that Australian homes would be more energy efficient if more of them were two-storey. **Justify** this statement by referring to other ways in which, despite the increased use of timber, two-storey homes are more efficient.

Answers and sample responses are available in your digital formats.

LESSON 9.3 Thermal efficiency

LEARNING INTENTION

In this lesson you will:
- identify heat and light as different forms of energy
- recognise that energy transfers via conduction, convection and radiation can be analysed in terms of energy efficiency
- explain how household energy consumption is affected by building design, season and climate, relative to the positions of the Earth and Sun to the seasons.

You have already learned how thermal energy is transferred by conduction, convection and radiation. Now, you will apply this understanding to explore how these processes affect the energy efficiency of homes.

9.3.1 Temperature regulation

The temperature outside changes with the seasons, region and time of day. It takes effort to keep the inside of a building comfortable. Windows made of glass can let sunlight in to warm the house and can open to let cool air in when it gets too hot. Fans and ducts circulate cool air from air-conditioning on hot days, and warm air from radiators, fireplaces or under-floor heating on cold days.

In each case, thermal energy is being redistributed due to the principles of **conduction**, **convection** and **radiation**.

In Australia's warmer climate, dealing with excess heat is a bigger problem than the cold. Heat is hard to control because it is produced by almost everything we do! Whether you exercise, cook, turn on lights or watch TV, you create heat. And if you go outside on a hot day, you let more heat in by opening the door.

Energy ratings for building materials, such as **R-values** for insulation and **U-values** for windows, help homeowners choose materials that improve energy efficiency. For example, double-glazed windows can reduce heat loss by 30–50 per cent compared to single-pane glass.

FIGURE 9.9 These solar panels in Canberra are angled upwards and to the north, so as to capture the most sunlight each day during summer.

For most homes, the most significant source of heat over time will be the Sun. Its warming effect is important year-round but most obviously in summer, for two main reasons.

- Due to the Earth's **axial tilt**, there are more minutes of daylight per day in summer, with the Sun spending longer at higher angles of elevation (and in the most extreme case, directly overhead). In the middle of the day, the atmosphere has less protective effect than at dusk or dawn, when the Sun's rays have to travel further through the atmosphere to reach us.
- There is usually less cloud cover in summer. In south-eastern Australia, long stretches of hot, dry days are typically driven by northerly winds, which are winds that blow from the north and bring hot dry air to Victoria each summer. Most of the clouds formed off the coast of Western Australia have long since gone by the time these winds blow their low-humidity air over to Victoria.

Building homes that are better adapted

Well-designed buildings incorporate features that moderate the impact of extreme weather. Some of the ways in which homes can be better adapted to suit the Australian environment include:

- *Improving thermal insulation* in walls and roofs, including draught reduction and double-glazed windows, reducing the rate at which energy can enter or leave the house
- *Increasing thermal mass* (by using brick, concrete, stone, mudbrick or hempcrete), meaning it takes a larger energy change to alter the building's temperature
- *Reducing direct sunlight on windows in summer* (but not in winter), which is achieved by building flatter roofs with wide eaves, and verandas at ground level
- *Reflecting more sunlight* (and hence absorbing less energy) by minimising use of north-facing windows and using lighter wall and roof colours
- *Improving airflow and ventilation* using roof chimneys and vents, open decks and verandas, and pairs of openable windows or doors on either side of the building, which allow natural air currents to remove hot air.

Combinations of these techniques will also be highly effective: solar shade sails, louvered slats outside windows, planting a 'green roof' garden on top of the building, using native trees to provide shade, paving paths and driveways with more-reflective materials and so on.

9.3.2 Thermal efficiency and conduction

The hotter an object gets, the more rapidly its particles (atoms or molecules) move. Thermal energy, which is observed as heat, is the rapid, random motion of particles — bouncing back and forth in all directions, frequently colliding with each other, as well as anything else nearby!

More heat means more energy and more rapid motion, so particles collide more often as an object is heated up.

For this reason, heat tends to spread rapidly through a substance, as those molecules that have already absorbed energy collide with the ones that have not yet been heated, passing on some of their energy. Heat can also spread from one object to another by the same means (called conduction) as long as they are in physical contact.

Insulation

Some materials are better at allowing heat to spread from one place to another; these are called thermal conductors. The opposite type of material is a thermal insulator.

As the outside surface of any building is always in contact with the surrounding environment, some conduction of thermal energy into (or out of) the building is unavoidable. Cladding the building in an insulating material might seem helpful, but the exterior of a building needs to fulfil a number of other functions. Materials that are weatherproof, robust, affordable, plentiful, structurally sound and pleasant-looking will rarely also be good insulators!

FIGURE 9.10 This insulation shares space inside the wall with wooden frames and electrical cables.

For this reason, an insulating layer is often included inside the structure. Boards of hard foam, blankets or batts made of densely packed fibrous strands, and even loosely packed pieces of infill materials may be preferred in different situations. Some are suitable for using between the exterior and interior walls, while others work better when laid flat between the roof and the ceiling. The intention is always to help slow down the rate at which thermal energy can enter or leave the building.

ACTIVITY: Heat flow without insulation

Sustainability Victoria estimates the breakdown of heat flow (into or out of a house) as follows. Note that this is for a hypothetical house built to modern standards but without any insulation.

	Ceiling	Windows	Walls	Air leakage	Floor
Winter losses	25–35%	10–20%	15–25%	15–25%	10–20%
Summer gains	25–35%	25–35%	15–25%	5–15%	Nil

When analysing this data, pay particular attention to these four key questions:

- Why would so little heat enter via the floor in summer, when a substantial amount of heat will leave the house via the floor in winter?
- Why would air leakage be a more significant problem in winter than in summer?
- Can you think of a reason why windows contribute more significantly to energy gain in summer than to energy loss in winter?
- Why would insulating the ceiling appear to have a greater impact than insulating the walls?

INVESTIGATION 9.1

Effective insulation

Aim

To test the ability of different materials to insulate against the flow of heat

Materials

- water bath (sink, wide plastic container, etc.)
- stackable, water-resistant containers (takeaway boxes, icecream tubs, cups, bowls, etc.)
- spacers (chopsticks, pens or pencils, etc.)
- ice cubes
- water from the hot tap
- possible insulating materials (bubble wrap, scrunched-up paper, beanbag pellets, etc.)
- stopwatch or mobile phone

Method

1. Place one of the empty stackable containers in the water bath.
2. Place three or four spacers around the inside of the stackable container.
3. Add another stackable container inside the first. There should be an air gap, due to the spacers.
4. Fill the air gap with one of the insulating materials.
5. Weigh out a consistent quantity of ice cubes (e.g. 50 g) into the upper stackable container.
6. Fill the water bath with hot water, to about half the height of the lower stackable container.
7. Record how long it takes for the ice cubes to melt.
8. Empty and dry the stackable containers and the water bath. When apparatus has returned to room temperature, repeat all steps for each of the remaining insulating materials.

Results

1. Record your data in a table.
2. Present your data as a column graph.

Discussion

1. Which material was the most effective thermal insulator?
2. Would this be a practical material to use on a large scale to insulate houses?
3. Which material was the most effective thermal conductor?
4. What variables were controlled during the experiment?

Conclusion

Write a conclusion to your investigation, summarising your findings and referring back to your aim.

Thermal mass

A building with thick, solid walls made from dense materials offers significant advantages in the heat of the Australian summer. Even if energy transfers due to conduction cannot be avoided, buildings with a greater thermal mass take longer to heat up and do not reach an uncomfortable temperature until later in the day — by which time, the outside air temperature may already have dropped as the sun sets or a 'cool change' arrives. They then take longer to cool down, which can be helpful at night when you might want to retain some of the heat of the day.

Having a larger thermal mass is also beneficial in colder weather if the temperature is warmer at night than during the day. Can you think why?

However, materials with greater thermal mass can present some challenges when it comes to insulating a building. A thick, solid wall made of stone, mudbrick or rammed earth does not have internal cavities that can be filled with foam boards or wool battens. Internal plaster walls can be added, but they reduce the available floor space. External cladding adds cost and complexity to a build.

ACTIVITY: Hot days, warm nights

The highest and lowest temperatures in the living spaces of two houses in Melbourne were compared over three summer days. One house had a greater thermal mass than the other.

	Overnight low	Daytime peak	Overnight low	Daytime peak	Overnight low	Daytime peak	Overnight low
External temperature	19°C	37°C	18°C	35°C	21°C	25°C	21°C
Low thermal mass	21°C	37°C	20°C	37°C	22°C	28°C	22°C
High thermal mass	21°C	29°C	21°C	31°C	23°C	27°C	22°C

What effect did the greater amount of thermal mass appear to have on:

- the daytime peak temperature on the first hot day?
- the daytime peak temperature on the second hot day in a row?

The City of Melbourne, along with many other municipal councils, recommend that buildings with a high thermal mass make use of 'night purging' — opening windows to allow retained heat to escape more quickly, bringing the building to the same temperature as its surroundings. How many degrees could the temperatures in these two houses have fallen each night if the occupants trialled this approach?

9.3.3 Thermal efficiency and convection

Conduction is an important way energy is transferred in solids, but it is not the only way or most important way for heat to enter or leave a building.

When heat is present in a fluid (such as a liquid or gas), the particles become freer to move around independently than they would in a solid. High-energy particles within hotter parts of the fluid will tend to spread out, forming lower density regions. The opposite is also true: low-energy particles in colder parts of the fluid will tend to condense, creating pockets of higher density matter.

Think about it like this: If you drop a heavy metal shotput and a lightweight piece of foam into a swimming pool, the shotput sinks because it is denser, while the foam floats because it is less dense. Similarly, if you pour cold water into a pool, it sinks to the bottom, and if you release hot tea underwater, it rises to the top.

Convection occurs when heat is transferred in and out of a fluid at different locations. Where the substance is being warmed up, hotter particles will start to rise to the top. Wherever the substance is being cooled down, particles will become colder and begin to sink.

Buildings are not as solid as they seem. Walls are often hollow, and there are gaps under doors and around windows where air can leak in and out. When we talk about 'heating our home', we are mostly talking about heating the air inside it.

On a cold day, most of the heat from a heater rises to the top of the room, which can be annoying. But on a hot day, you might be glad there is somewhere for the heat to go when you are cooking dinner.

FIGURE 9.11 Convection of air inside the wall will circulate heat up towards the vents that you can see on the brick wall in this photo, cooling the building as the hottest particles escape into the surrounding environment.

In bigger buildings, this becomes a bigger problem. For example, it would not feel fair if your top-floor apartment was always hotter than everyone else's, especially if your downstairs neighbours kept using their ovens during summer!

SCIENCE AS A HUMAN ENDEAVOUR: The Queenslander

The Queenslander is a distinctive style of house named after the state in which they first became common. These houses were first built in the 1840s and are still popular today. They were made from lightweight, local materials such as corrugated iron and local timber. They were low-cost, readily available and able to withstand the region's high temperatures and subtropical humidity.

FIGURE 9.12 Part of a typical Queenslander house

To deal with heavy seasonal rainfall, the houses were raised on stumps or stilts, which helped prevent flooding and allowed airflow underneath the house, providing additional cooling in summer and keeping the timbers dry in damp conditions.

Another key architectural feature were the verandas that wrapped around the house, shielding the exterior walls and windows from the summer sun. These outdoor areas expanded the available living space and allowed larger families to live in relatively smaller (and therefore affordable) houses. The roofs were usually painted white to reflect sunlight and keep the house cooler.

With doors and windows positioned on opposite sides of the house, and breezeways placed above any internal doors, cross-ventilation would have allowed naturally occurring sea breezes to move hot air out of the house. With high ceilings (3 to 4 m), hot air could rise, making the house cooler and easier to sleep in during hot months. The lightweight materials also meant the house could cool down quickly at night.

1. How do the cooling features of the Queenslander style compare to traditional house designs in other hot climates, such as the architecture of the Mediterranean or the Middle East?
2. How might the Queenslander design need to evolve to address current and future climate challenges, such as increased temperatures or more extreme weather events?

Proposed scientific responses to socio-scientific issues impact on society and may involve ethical, environmental, social and economic considerations (VC2S8H03)

9.3.4 Thermal efficiency and radiation

In addition to conduction and convection, the third way heat transfers is through radiation.

Any kind of light can be described as radiation, and all kinds of light travel at the same speed — about 300 000 000 m per second! This means that radiation can be a very fast way to transfer energy over long distances, and is, in fact, the only one of the three methods by which the Sun's thermal energy can reach Earth!

Light is created from other types of energy and is 'emitted'. Everything is always emitting light, even if it cannot be seen. Right now, you are emitting light because of your body heat! Though it is not visible, an infrared camera would show you glowing.

When light arrives at a surface, it can be absorbed and turned back into another form of energy (usually heat). The other possibilities are that the light can be transmitted, passing into and through a material, or that it can be reflected.

To understand how this could be related to the thermal efficiency of a building, the focus will be upon the ability of each surface material to reflect and emit light.

For a building to stay cool when in direct sunlight, it is useful for each of its surface coatings to reflect as much light as possible. However, if those surface materials were also poor at emitting light, the building would be less able to shed heat overnight (or at least, not by the means of emitting radiation; it could still get rid of heat by other means, such as passive cooling due to cross-ventilation).

FIGURE 9.13 Half of this house has been modernised, with new insulation and a surface coating that reflects more light.

EXTENSION: Albedo and emissivity

Albedo measures how well a surface reflects light. **Emissivity** measures how well a surface emits light. Both are expressed as a ratio between 0 and 1, where 0 means 'not at all' and 1 means 'perfectly'.

Bare metal surfaces tend to have a very low emissivity. The albedo can be high, but only if the metal is well-polished.

White and black paint usually have a very high emissivity, but their albedos are at opposite ends of the scale: one reflects almost all light, while the other reflects very little!

Reflective materials are also useful on the insides of houses. Chances are the room you are in now has bright white or near-white walls. This helps keep heat inside the house at night and allows just a few small electric light sources to fully illuminate each room. The foam boards used for insulation in many homes can also have a reflective foil backing, improving their ability to prevent thermal energy travelling through the insulated wall or ceiling. Reflective materials will generally be most effective when they face onto a room, wall cavity or other air gap — if they are in direct contact with another part of the house, they may simply conduct thermal energy instead!

SCIENCE INQUIRY: Solar exposure

What factors have determined the weather you are experiencing today? A reasonable hypothesis would be that the amount of sunlight a location on Earth receives in a day will have a significant impact on the temperature. Factors influencing the amount of sunlight could include cloud cover, latitude and time of year.

The Bureau of Meteorology publishes a variety of relevant data sources that you can explore:

- Average maximum, minimum and mean temperatures (historical to 2020, annual or per month)
- Average daily sunshine hours (historical to 2003, annual or per month)
- Average daily solar exposure (historical to 2019, annual or per month)
- Daily solar exposure for Australia (current day only)

These questions could be used to guide your investigation:

- What relationship (if any) can be observed between mean temperature and daily sunshine hours? Is this consistent across the different months of the year?
- If you download copies of the average daily solar exposure map each lesson for a week, you can then compare your collated data to the historical trend for the current month. Are there any noticeable similarities or differences?

- A traditional European model of four seasons, each of equal length, does not always adequately explain the variation in weather seen throughout the year in Australia. What system of seasons (or other annual calendar) is recognised by the traditional owners of the land where your school was built? Does this better match the variation you see in the Bureau's maps of historical data?
- If your house or school operates solar photovoltaic panels, you may also have access to data about the amount of energy produced by those panels at different times of the year. It could be interesting to compare this to the general trends shown in the Bureau's data; can the amount of energy produced each month be related to the amount of sunlight available to the panels?

Data and information can be organised and processed by selecting and constructing representations including tables, graphs, keys, models and mathematical relationships (VC2S8I04)

9.3 Activities

learnon

9.3 Quick quiz on	9.3 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 6	3, 5, 9	4, 7, 8, 10

Remember and understand

1. **List** materials that can be used to increase the thermal mass of a building.
2. **State** the reasons that more solar energy will be absorbed by a building in summer than in winter.
3. Classify each of these as an example of conduction, convection or radiation:
   a. You can feel the heat of a fire on the palms of your hands while standing a few metres away.
   b. The inside surface of a pane of window glass feels cold to the touch on a frosty morning.
   c. Ducted heating is most effective when the heated air is released from floor level.

Apply and analyse

4. **Distinguish** between electrical insulators and thermal insulators.
5. **Clarify** why the direct warming effect of the sun on a building is reduced in the early morning and late afternoon, when it is lower in the sky.
6. **Compare** the concept of a house having greater thermal mass to the idea of trying to boil a larger amount of water in a kettle. How long would it now take to heat up? To cool down?
7. SI In colder climates, coal- and gas-fired power stations can channel their waste heat to nearby houses, condensing steam to make a steady supply of hot water. This delivers the thermal energy needed to power the houses' underfloor hydronic heating systems.
   Outline the ways in which this improves:
   - the energy efficiency of the power plant
   - the thermal efficiency of the homes.

Evaluate and create

8. **Propose** a reason for the 'urban heat island' effect, whereby built-up areas such as cities become noticeably warmer than suburbs and rural areas on days when the sun is not obscured by clouds.
9. SI Think about designing a house. **Summarise** the three main ways that heat energy can be transferred into the building from the outside environment on a hot summer's day.
10. SI The COLORBOND® range of painted steel includes the following colours (from light to dark): Shale Grey, Bluegum and Basalt. This material can be shaped into various patterns and may be used as a wall cladding, or as a roofing material.
    Evaluate each of these options for possible use in a mountainous part of Victoria, where overnight temperatures in winter often drop below 0 °C and daytime temperatures in summer can exceed 40 °C.

Answers and sample responses are available in your digital formats.

LESSON 9.4 Electrical efficiency

LEARNING INTENTION

In this lesson you will:
- relate appliance choice to household energy consumption
- discuss considerations (ethical, environmental, social and economic) related to energy transfers and transformations in homes.

9.4.1 Appliance ratings and energy efficiency

Choosing energy-efficient appliances can make a big difference in how much energy a household uses and how much money it spends on electricity bills. In Australia, electrical devices are given an **energy rating**, shown as a number of stars from 0 to 6. The more stars the product is given, the more energy efficient it has proven to be when tested according to the relevant Australian standard (e.g. *AS/NZS 4474* is the Australian and New Zealand standards document outlining the requirements for refrigerating appliances). **Super-efficient appliances** can even receive a rating of over 6 stars, in which case up to 4 additional stars can be added!

FIGURE 9.14 The energy rating system makes it easier to compare different makes and models of appliance.

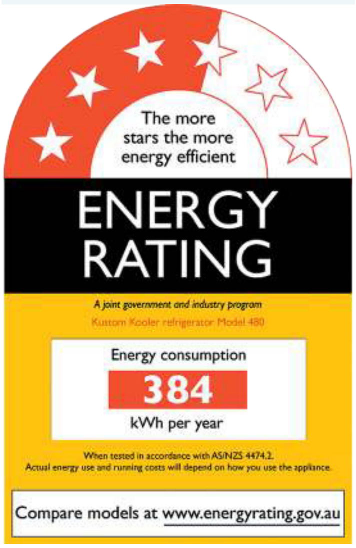
Why appliance ratings matter

- *Energy cost savings* — More efficient appliances use less electricity, which can lower your power bill.
- *Environmental impact* — Reducing energy use means less fossil fuels burned, which helps reduce greenhouse gas emissions.
- *Comparing appliances* — Ratings allow us to easily compare different models to pick the best one for our needs.

How ratings work

- *Power rating* — Measured in watts (W), it shows how much energy an appliance uses per second when operating.
- *Energy consumption* — Often given as kilowatt-hours (kWh) per year, showing how much energy it uses over time. A kilowatt-hour is the energy used by a 1000-watt appliance in one hour. This is key when comparing long-term costs.
- *Efficiency labels* — Australian appliances come with labels showing their star rating and estimated annual energy consumption. This helps consumers make informed choices at a glance.

FIGURE 9.15 Appliance labels display a star rating and an estimate of the energy consumption per year.



- Energy = Power × Time: This formula helps calculate energy consumption by multiplying power (watts) by time (hours).
  For example, say a 100-watt fan runs for 5 hours.
  Energy = Power × Time
  Energy = 100 W × 5 hours
  Energy = 500 watt-hours
  Since 1000 watt-hours = 1 kilowatt-hour, this means the fan uses 0.5 kWh of energy over 5 hours.
  If electricity costs 25 cents per kWh, running the fan for 5 hours would cost 12.5 cents.

SAMPLE PROBLEM 2: Comparison within a category

A refrigerator receives a rating of 4 stars, while another manufacturer produces a similarly sized model that receives $4\frac{1}{2}$ stars. What conclusion can you draw about these two appliances?

THINK	WRITE
Both appliances would be tested according to the same standard. They can be directly compared. The highest rated device has a reasonable energy efficiency, because this is a 6-star scale.	The appliance that received $4\frac{1}{2}$ stars is more energy efficient and would use less energy per year.

SAMPLE PROBLEM 3: Cross-category comparison

A freezer receives a rating of $3\frac{1}{2}$ stars, which is the same rating given to a television produced by a different manufacturer. What conclusion can you draw about these two appliances?

THINK	WRITE
These appliances would be tested according to different standards. They cannot be directly compared. Both devices have a fairly low energy efficiency, because this is a 6-star scale.	We cannot determine how much energy each uses per year without referring back to the relevant testing standards.

INVESTIGATION 9.2

Maximising appliance efficiency

Aim

To investigate how different usage habits affect the energy efficiency of household appliances

Materials

- energy meter (or smart plug with energy monitoring features)
- notebook or data sheet for recording results
- appliances to test (e.g. fridge, TV, washing machine, heater or fan)

Method

1. Select 3–4 common household appliances to investigate.
2. Use an energy meter to measure the appliance's energy usage over a set period (e.g. one hour, one day or one cycle for devices such as washing machines).
3. Compare the energy consumption of different usage settings (e.g. using a washing machine on a cold vs. hot cycle, running a fan on high vs. low speed).

4. Record and analyse the differences in energy consumption.
5. Identify patterns and make recommendations for improving energy efficiency.

Results and analysis

- Present your data in a table or graph.
- Identify which settings and habits result in the most energy-efficient use of appliances.

Discussion

1. Which appliances consumed the most energy? Why?
2. How did different settings (e.g. temperature, speed or cycle duration) affect energy use?
3. What simple changes can be made to household habits to improve efficiency?

Conclusion

Summarise the key findings and suggest practical actions households can take to reduce energy consumption while maintaining convenience and comfort.

SCIENCE AS A HUMAN ENDEAVOUR: Star rating systems

You might know other star rating systems. Many food products show health star ratings to compare products within the same category. App stores, online shops and ride-share apps use customer ratings to help buyers choose. Sometimes, the seller or service provider also rates the customer!

Often, ratings are compressed. Even though there is a five-star system, an average of four stars might still be seen as bad service. Each rating system must be learned in its own context.

Rating scales can change over time. A five-star rating used to be great for appliances, but now it is a six-star scale because new appliances are more efficient.

1. Select another star rating system and compare it to the energy rating system for appliances. Research each system to find out:
   a. how many stars the system uses for ratings
   b. how the rating is determined
   c. whether it is possible to receive a rating higher than 100 per cent
   d. if (and why) the system has changed over time.
2. Critique the two systems. What is good about each of them? What could be difficult to understand or hard to use? Do you prefer one system over another and, if so, why do you think that is?

Communication of scientific knowledge has a role in informing individual viewpoints, and community policies and regulations (VC2S8H04)

9.4.2 Calculating efficiency

Many appliances continue to use electricity even when switched off — this is called standby power or 'phantom load'. Households can save up to 10% on electricity bills by unplugging devices or using smart power strips.

You can use the concept of efficiency to analyse many different processes, as long as the input and output are measured in the same way. Before calculating the efficiency of a process, you always need to ensure that both values were stated in comparable units. If they are similar, but one is measured in a larger or smaller unit than the other, a simple unit conversion will be required before you can perform the main calculation.

FIGURE 9.16 Compared to filament-style bulbs, compact fluorescent lights provide the same energy output while requiring much less energy input.

Efficiencies cannot be more than 100 per cent because that would mean creating something from nothing. If your calculation shows more than 100 per cent, check your work — you might have missed some inputs or mixed up the input and output.

KEY IDEA

The efficiency of any process that turns an input into an output can be calculated, so long as both are measured in the same way.

$$\text{efficiency} = \frac{\text{useful output}}{\text{input}} \times 100\%$$

Dividing the output amount by the input amount gives a value which:

- is a dimensionless ratio (i.e. it does not have any units)
- is multiplied by 100% to express the efficiency as a percentage
- ranges between 0% (totally inefficient) and 100% (totally efficient)

SAMPLE PROBLEM 4: Recycling cardboard

A recycling plant is able to make 750 kg of cardboard boxes from 2 tonnes of waste paper. Find the efficiency of this process.

THINK	WRITE
Notice how the output is in kilograms, so the input value in tonnes has to be converted into kilograms before performing the calculation, using the ratio: 1 tonne = 1000 kg	$\text{efficiency} = \frac{750\text{ kg}}{2000\text{ kg}} \times 100\%$ $= 37.5\%$

PRACTICE PROBLEM

A filament light globe requires an input of 70 joules (J) of energy to produce 7 J of useful energy output. The rest of the energy is wasted as heat.

A compact fluorescent light (CFL) that fits into the same light socket can produce the same 7 J of useful energy output while needing to use only 10 J of input energy. Much less heat is produced.

Find the efficiency of each light bulb, and hence explain the advantage of replacing filament globes with CFLs.

9.4.3 Ethical, environmental, social and economic considerations

Two main factors affect the amount of energy used by a household: the number of people living in the home and the combined income of those individuals. Unsurprisingly, larger households use more electricity, but so do those with incomes that are significantly higher or lower than average.

In part, this may be because highly efficient appliances tend to come with a higher price tag. They will of course save energy, leading to a net financial benefit over the life of the appliance, but the up-front cost can be prohibitive. Large, low-income families tend to have the highest power bills of all. These families would likely benefit the most from government assistance to purchase more efficient appliances.

DISCUSSION

What other reasons can you think of to explain the higher energy usage of:
- higher income households
- lower income households?

When considering the energy used by an appliance over its entire life, we should also think about:
- the environmental impact of its raw materials
- manufacturing processes
- packaging materials
- transportation
- the recycling potential of the older model it replaces.

FIGURE 9.17 This modern cooktop features gas burners as well as electric induction heating elements.

Even if households could afford the most efficient appliances, the energy used to make and run them might still come from inefficient or harmful sources, creating an ethical challenge. Homeowners can reduce their impact by using renewable energy generated from solar panels, wind turbines or hydroelectric generators, all of which work well in Victoria due to its geography and climate.

However, transporting electricity over long distances is costly and leads to energy losses. Many renewable energy sources cannot meet rising demand during peak times, such as in the evening. Energy storage options, such as hydroelectric dams and batteries, can help but are expensive and may harm the environment. Natural gas, a cheaper, on-demand energy source, is still used despite its emissions.

Natural gas is also common in homes for ovens, hot water and heating. Over time, gas appliances are being replaced by electric ones, which waste less energy, help keep homes cooler in summer and reduce indoor air pollution. Some new housing developments rely entirely on electricity without gas lines — a trend called **degasification**. Financial support may be needed to help households upgrade their appliances.

DISCUSSION

The degasification of homes in Victoria has not been universally applauded. To understand why, imagine if the state or federal government promoted removing traditional petrol and diesel cars from our roads in order to make way for more efficient electric vehicles. In practice, of course, that particular change is already occurring — driven not by government policy so much as consumer demand for less-polluting vehicles that are also cheaper to run — but there will always be members of the public who bristle at the idea of restrictions being placed on consumers' ability to choose for themselves!
- Do you have strong opinions, one way or the other, about a change from gas to electricity as the main energy source in our homes?
- If you were a government advisor, what strategies would you suggest they use to build public acceptance for these kinds of changes?

SCIENCE INQUIRY: How do we heat and power our homes?

Aim

To investigate the different energy sources used for heating, cooking and hot water in households, considering a diverse range of cultural and regional factors

Task

Design and conduct a survey for class members to take home to find out how different households meet their energy needs.

The three different energy uses to be investigated are:

1. heating the home
2. heating water
3. cooking.

Survey questions

For each category, respondents should be asked:

- *What energy source(s) do you use?* (Tick all that apply.)
  - Mains electricity
  - Mains gas (natural gas)
  - Bottled gas (LPG)
  - Solar energy (e.g. solar hot water, solar panels)
  - Wood (e.g. fireplaces, wood-fired stoves)
  - Diesel or petrol (e.g. generators, kerosene heaters)
  - Other (please specify)
- *Why do you use this energy source?*
  - Availability
  - Cost-effectiveness
  - Cultural/traditional preference
  - Environmental considerations
  - Other (please specify)

FIGURE 9.18 A fireplace is one way to heat a household.

Considerations

- Some cultures and communities prefer traditional cooking methods, such as wood-fired ovens, charcoal stoves or biogas.
- Some regional areas rely on different heating methods, such as kerosene or diesel generators, while others use passive solar heating.
- Financial and geographical factors may influence energy choices.
- Survey respondents should be informed about how the data will be used before being asked to participate. Research investigations must always seek informed consent, and participants have the right to withdraw even after the survey has been conducted.

Data collection & analysis

- Ensure that each household is surveyed only once for accuracy.
- Organise the responses in a spreadsheet and categorise different energy sources.
- Compare the results in graphs or charts (e.g. pie charts, bar graphs).
- Discuss how cultural, financial and environmental factors influence energy choices in different households.

Discussion questions

1. What are the most common energy sources used in your community?
2. How do cultural traditions influence the way people use energy at home?
3. How do different energy choices affect energy efficiency and sustainability?
4. What alternative energy sources could be promoted to improve energy efficiency in different households?

Information and processed data can be analysed to show patterns, trends and relationships, and to identify anomalies (VC2S8I05)

9.4.4 Smart homes and sensors

As homes grow larger, better lighting is added and homes become populated with ever-greater numbers of powerful electrical devices. There is a greater potential than ever before for energy to be wasted if appliances are left running unnecessarily — but luckily, there are also better opportunities to control and limit wastage through the use of **smart homes** and **sensors**.

Think back to the last week or so; you might recall times when you left a room without switching off the lights, left the TV running while your focus was elsewhere or had to re-boil a kettle to make a hot drink because you were distracted by something else and let it cool down. Maybe you are good at saving energy, but it can be frustrating when other family members leave lights on when they go out.

FIGURE 9.19 If even a few of these lit rooms are unoccupied, there is an opportunity to reduce energy usage.

A smart home setup lets you control appliances remotely, using voice commands or an app on your smartphone. Sensors can make sure lights are only on in rooms where people are, or turn them on when you enter. You can also set up automation for energy-saving tasks, such as closing blinds or opening windows, based on timing or events (such as sunset or coming home from work).

However, these systems cost money to set up and need technical know-how. Even a smart lightbulb that needs an app can be difficult for low-income households or people who are not tech-savvy.

DISCUSSION

A two-decade-long study of housing utilisation found that the size of Australian households remained stable, with an average of 2.7 persons, while the average size of homes increased slightly, from 3.0 to 3.1 bedrooms per dwelling. By 2020, more than three-quarters of households reported having at least one spare bedroom, with only four per cent of households having too few bedrooms for the number of people living at that address.

You may recall that 2020 was also a year that dramatically changed how many Victorians lived and worked, with spare rooms often being converted into home offices during the government-mandated lockdowns in response to the COVID-19 pandemic. Some businesses responded by downsizing, reducing the amount of commercial office space they were renting.

The question of efficiency is a complex one, but well worth considering and debating.

- Propose arguments supporting the statement: ‘It would be more efficient for Australia to go back to building smaller homes.’
- What arguments can you suggest that might instead support the thesis: ‘Remote work makes it possible to improve efficiency by building larger homes.’
- In future, there might be ever-smaller households living in ever-larger homes. How might this increase energy costs, and what opportunities would smart home technology offer for reducing this energy use?

9.4 Activities

learnon

9.4 Quick quiz on	9.4 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 5	4, 7, 9	6, 8

Remember and understand

1. MC Which factor most affects how energy efficient an appliance is?
   A. The brand of the appliance
   B. How often the appliance is used
   C. The appliance's Energy Rating
   D. The colour of the appliance
2. **Identify** one (or more) Energy Rating(s) that could be found on a super-efficient appliance.
   a. $3\frac{1}{2}$ stars
   b. 5 stars
   c. 6 stars
   d. $7\frac{1}{2}$ stars
3. MC Which of the following factors is most likely to increase a household's energy consumption?
   A. Using energy-efficient appliances
   B. Keeping windows open in winter
   C. Turning off lights when leaving a room
   D. Installing solar panels
4. **State** the reasons that degasification of homes can lead to improved efficiency.

Apply and analyse

5. **Clarify** why you cannot calculate the efficiency of a process that uses a known amount of energy to manufacture a certain number of panes of glass. **Suggest** what additional information you would need in order to find the efficiency of this process.
6. **Calculate** the power rating of a kettle, if it takes 1 minute and 20 seconds to deliver 176 400 J of energy (enough to heat 600 mL of water to a temperature slightly below the boiling point).
7. SI **Outline** the ways in which a 'smart home' setup, using suitable sensors, could improve the energy efficiency of your classroom. If such a system is already in place, explain how it works!

Evaluate and create

8. SI Design your ideal smart home setup, listing its key features. **Explain** the design and **justify** your design choices.
9. Create a top-20 list of key ideas relating to the topic title, Energy efficiency, and **construct** a mindmap showing the links between these ideas.

Answers and sample responses are available in your digital formats.

LESSON 9.5 Auditing your energy use

LEARNING INTENTION

In this lesson you will:
- represent energy transfers and transformations in a simple system
- undertake a household energy audit
- propose ways to decrease energy consumption.

9.5.1 Measuring energy

Smart meters and energy monitoring apps allow homeowners to track real-time electricity usage, helping them identify wasteful appliances and adjust habits to improve efficiency. The SI unit for energy is the **joule (J)**. One joule is not a very large amount of energy, and if power companies were to charge consumers per joule used then the dollar value per unit would be a miniscule amount. To put this in perspective: watching TV for an hour might use a few hundred thousand joules, while the average Australian needs to consume almost nine million joules' worth of food and drink per day! Instead of charging customers by the joule, power companies use a larger unit called the **kilowatt-hour (kWh)**.

KEY IDEA

In 2024, electricity in Australia cost between \$0.25 and \$0.45 per kWh, depending on location and energy plan. This unit is more practical for billing than using joules, which are worth far less. A kilowatt-hour equals a fixed number of joules.

$$\text{Energy in J} = \text{Energy in kWh} \times 3\,600\,000$$

$$\text{Energy in kWh} = \text{Energy in J} \div 3\,600\,000$$

The reason that the kilowatt-hour is equal to a particular number of joules is that there are 1000 W in a kilowatt, 60 minutes in an hour and 60 seconds in a minute. The conversion factor from kWh to J is the product of these three numbers. It may help to realise that a joule is a 'watt-second'.

A common mistake made by students encountering kilowatt-hours for the first time is to assume that they must be similar to the more familiar idea of kilometres per hour. However, the flawed concept of a 'kilowatt per hour' is not logical: the watt, which is the unit of **power**, *already* measures energy over time, so there is no need to divide by time again! Once you understand that kilowatt-hours is a unit of power multiplied by a unit of time, it should be easy to relate this to the formula **energy = power × time** and understand that kilowatt-hours is a measure of energy.

EXTENSION: Milliamp-hours

The energy content of a rechargeable battery pack is often rated using a different unit, called the milliamp-hour (mAh). Particularly large battery packs could also have a value in amp-hours (Ah), or even kiloamp-hours (kAh). These measurements can be converted to more familiar units (kWh, J) if you also know the voltage of the battery. This works on the principle that **power = voltage** × **current**, that is, watts = volts × amps.

SAMPLE PROBLEM 5: Capacity of a battery pack

If a battery pack has a rating of 8800 mAh at a voltage of 3.7 V, how much energy does it store:

a. in mWh?
b. in Wh?
c. in kWh?
d. in J?

THINK	WRITE
a. **Power = voltage × current**, so the amount of milliwatt-hours is equivalent to the capacity in milliamp-hours multiplied by the voltage.	a. 8800 mAh × 3.7 V = 32 560 mWh
b. There are 1000 milliwatt-hours in a watt-hour.	b. 32 560 mWh ÷ 1000 = 32.560 Wh
c. There are 1000 watt-hours in a kilowatt-hour.	c. 32.560 Wh ÷ 1000 = 0.032560 kWh
d. There are 3 600 000 joules in a kilowatt-hour.	d. 0.032560 kWh × 3 600 000 = 117 216 J

ACTIVITY: Energy consumption in Australian households

In mid-2021, the average amounts of energy used by Australian households were as follows:

	Low-income dwellings (kWh/day)	High-income dwellings (kWh/day)	All dwellings (kWh/day)
1-person	11.9	16.6	12.6
2-person	16.2	19.2	16.6
3-person	19.8	21.3	19.8
4-person	22.7	24.0	22.5
5-person or more	26.7	26.6	25.5

1. What was the average cost of energy per day to households of different sizes, if they were billed 35 cents per kWh?
2. Did Australians use more energy per person in larger or smaller households? Suggest reasons why.
3. How did the energy use for low-income households compare to the average across all dwellings? Did this depend on the number of members in the household? Can you explain why this might have been?

9.5.2 Electricity, gas and water bills

Utility companies supplying consumable goods to your house will bill you, typically monthly or quarterly, for several things:

- A **service charge**, covering your fair share of the installation, maintenance and upgrade costs of the entire supply network. This is payable even if you do not use any power/gas/water during the billing period!
- A **usage charge**, covering the actual or estimated amount of power/water/gas you actually used. There may be price bands, with the price per unit becoming higher as your usage goes up. This provides a financial incentive to reduce your use and improve the efficiency of your home, as well as having any leaks promptly repaired by a tradesperson such as an electrician or plumber.
- On water bills only, a **sewage charge** covering the cost of removing and treating wastewater from your property. This is a pro-rata amount, meaning that it is based on the amount of water you actually used, but also covers the cost of removing stormwater and other run-off that has flowed into your property's drains and roof gutters.

The supplier may also provide additional information, such as a baseline for comparison or the carbon cost of the energy and materials supplied to your home.

KEY IDEA

The units of measurement on a utility bill vary according to what is being measured:

- Electricity bills measure energy in units of kilowatt-hours (kWh)
- Gas bills measure energy in units such as megajoules (MJ)
- Water bills measure liquid volume in units such as megalitres (ML)

Note the difference between the prefixes milli (lowercase m) and mega (uppercase M).

To directly compare electricity and gas usage, remember that 1 kWh = 3 600 000 J = 3.6 MJ.

DISCUSSION

The Australian Bureau of Statistics (ABS) conducts a census every five years to collect data about every Australian household. Reflecting on data collected during the 2021 census, as well as information available from energy retailers, they noted that:

'Average daily electricity use was lower for dwellings where the main source of income was age pension compared with disability support pension or wages/salary.'

An age pension is a government payment for people who have reached retirement age.

1. What does this suggest about the relative cost of electricity?
2. Aside from being price-conscious, what other reasons might there be for households reliant on an age pension to use less energy?

Where the actual usage cannot be known precisely, a seasonally adjusted estimate (which may be based on your past use and that of other similar properties nearby) will be used instead. If you have a manual water meter or gas meter on your property, an employee of the utility company will visit periodically to read the meter. Sometimes these meter reads line up well with the billing period, so the usage recorded on the bill will be quite accurate; at other times, the meter reads and billing cycles are not well synchronised, and there may be some discrepancies. Utility companies may allow you to report a 'self-read' of the meter (with photographic evidence) to help improve the accuracy of the next bill.

FIGURE 9.20 Utility companies can supply electronic copies of your bills, or post them out to you.

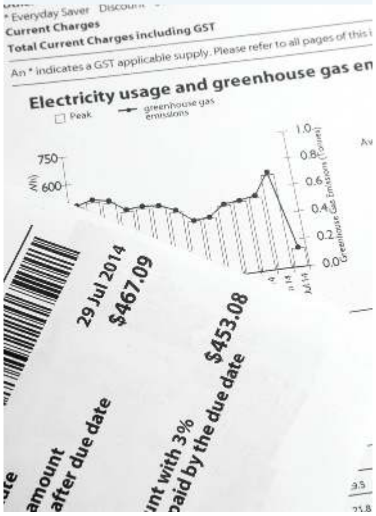


FIGURE 9.21 A household gas meter

The reporting of electricity usage is generally much more accurate. This is because smart meters have been mandatory in new buildings constructed in Victoria since the late 2000s. Smart meters have also been retrofitted to many existing homes, replacing the existing **accumulation meters**, and the target is for all homes to have one by 2030.

DISCUSSION

After completing the 2021 census, the ABS concluded that around 11 per cent of Victorian homes were unoccupied on the particular night the census was conducted. There could be various reasons for this: the household may have been on holiday, or staying in hospital; a dwelling may have been unoccupied due to ongoing renovations; rental properties will not always have had tenants, etc.

An empty property will still incur service charges from each network (electricity, gas and water) unless and until the account holder requests these services be disconnected. These charges help pay for the maintenance and modernisation of the entire network, but it is reasonable for a homeowner to opt out when they know that no services are going to be used at the property. Reconnection of services, for example when a new tenant moves into a rental property, is easy and usually very efficient.

- What are some pros and cons of the system being set up in this way?
- Brainstorm ways in which an unoccupied house might still be using electricity, gas and/or water.
- If a house was going to be unoccupied for some period of time, but the homeowner did not want to ask for their services to be disconnected, what could they do to reduce their utility bills?

SCIENCE INQUIRY: Increasing the utility of your bills

Aim

To collect a number of utility bills, and to determine improvements to their design and layout so that scientific data can be communicated to customers in a more accessible manner

Task

Power and water bills can include a *lot* of data. Depending on your use case (e.g. paying the bill on time, comparing plans and prices between retailers, analysing the efficiency of your home) only some of this information will be useful and relevant, while the rest may be an unwelcome distraction!

Energy and water retailers may offer consumers the choice of 'going paperless': receiving bills via email or by logging into a secure website, rather than in the post. However, the design of these electronic documents is often near-identical to their paper equivalents, offering little improvement in terms of the customer experience.

Each class member may be able to supply one or more examples of utility bills sent to their household within the last year. These should be redacted (removing any personally identifying information and any specific details about usage or charges) before they are shared with the rest of the class. A teacher may be able to assist with obscuring or deleting unnecessary or personal data, and this process may be streamlined if electronic copies of documents can be supplied.

By comparing and discussing these examples as a class, determine:

- what information is being conveyed and whether it is easy to locate that information
- what features of a bill generally make it more readable or easy to understand
- what features of a bill generally make it less readable or difficult to understand
- whether the bill made effective use of its format (i.e. as a printed or digital document).

Individually or in small groups, propose a new format for a bill that communicates the same information in a more accessible way.

You could sketch this out on paper, or use suitable layout and editing software to produce a digital mock-up of your design.

Evidence-based arguments can be constructed to support conclusions or evaluate claims, including consideration of ethical issues and protocols associated with using or citing secondary data or information (VC2S8I07)

SCIENCE AS A HUMAN ENDEAVOUR: Electricity supply and load

Electricity is supplied to your home by the combined efforts of different companies:

- generators, who make the power
- distributors, who build and maintain the network to deliver power to homes
- retailers, who manage contracts, connections and billing with customers.

FIGURE 9.22 Fossil fuels can always be combusted, even when the weather conditions are unsuitable for generating wind and solar power.

Customers pay a retailer for the energy they use. The retailers in that area pay the distributor, and the distributor sets aside some money to pay the generators. Everyone has to cover their costs and try to make a profit. It is not profitable for anyone if the generators stop working!

An emerging problem, related to the large increase in the proportion of our energy that comes from renewable resources, is the load placed on thermal powerplants at times when demand is high and neither solar panels nor wind turbines can meet consumer needs. Burning extra coal or gas is one way to meet rising demand, but every facility (and even each wire carrying power to our homes) has its limits. Production might not scale up quickly enough, and coal and gas plants might already be at full capacity.

In these situations, electricity network operators have to make a difficult choice between several bad options.

- Do nothing, and the entire network may collapse, with significant damage to generators and power lines. This will result in many or all consumers experiencing **blackouts**: periods of extended power loss, of uncertain duration.
- Lower the output power to all customers, with everyone experiencing **brownouts**, during which lights may dim and appliances may malfunction. Note that this may include critical infrastructure such as cold storage refrigeration units, fuel pumps and life support systems in hospitals!
- Temporarily disconnect some customers from the network, so that others can continue to receive power. This is called **load shedding** and it is generally seen as the better option, as it will not cause long-lasting damage to the network and can sometimes even be pre-planned and communicated to customers ahead of time, for example when extreme heatwaves are predicted to be combined with high winds and dust storms.

Imagine that you and your classmates work in a variety of different professions that would all be affected by any sudden loss of power (e.g. looking after intensive care patients in a hospital; managing a chain of petrol stations; overseeing distribution of frozen foods at a supermarket warehouse). Some of you could also represent other parts of society, such as residential homeowners, school principals, office workers, train drivers and so on.

Now, imagine that the decision needs to be made about who will temporarily lose power due to load shedding. What arguments would each person make about their need for an uninterrupted supply?

Proposed scientific responses to socio-scientific issues impact on society and may involve ethical, environmental, social and economic considerations (VC2S8H03)

9.5.3 Conducting a home energy audit

In the 2022–2023 financial year, the ABS identified about 420 000 first home buyers. Only 17 per cent (about one in six) of the dwellings they purchased were newly built. This means that the majority of first homes purchased in that year had previously been occupied by at least one other household. The efficiency of each dwelling built has lasting impacts, often across multiple generations. For most Australian homeowners, identifying ways to improve the efficiency of their existing building is a far more realistic option than planning a high-efficiency new build.

A home energy audit allows strengths and weaknesses of the existing home to be assessed. This can include assessing its architectural design and materials, as well as the appliances used within the home.

Summarising the major *Plan Melbourne 2017–2050 report*, the City of Melbourne state their plan to:

‘Improve energy, water and waste performance of buildings through environmentally sustainable development and energy efficiency upgrades’

After auditing your own home, you might be able to identify energy efficiency upgrades or other ways to improve its performance.

DISCUSSION

Maintaining and updating existing buildings can be much more cost-effective than building new ones. In 2019–2020, a comparison of housing costs for Victorian families who owned or were a paying off a mortgage for their own home, compared to those who rented, found that:

- owners without a mortgage paid $57 a week on average
- owners with a mortgage paid $501 per week, or 16 per cent of gross weekly household income
- renters paid $388 per week, or 19 per cent of gross weekly household income.

1. Which (one or more) categories of households have housing costs related to the initial cost of building their home, as well as its ongoing maintenance and upkeep?
2. Which category of household only has to pay housing costs associated with maintenance and upkeep of their home?
3. What conclusion can be drawn about the relative cost of building a new dwelling, versus the cost of maintaining an existing one?

Collecting the data

Depending on the time and materials available, a home energy audit can be a more or less extensive process. You will need to decide on the scope of your own energy audit, and use this to identify relevant observations and data that needs to be collected.

As one example, some councils make home energy audit kits available through local libraries. These feature measurement devices that can be used to assess:

- the flow rate of water in your showers
- the rate of electricity consumption of your electrical devices
- the thermal efficiency of your home, using an infrared camera to identify areas with poor insulation, etc.

FIGURE 9.23 The infrared spectrum of electromagnetic radiation reveals parts of a building that are hotter and cooler.

This requires expensive and complicated equipment, such as a thermal imaging camera. Nice if you have one, but not something every household will have access to!

Even without specialised equipment, though, there are plenty of things you can measure and assess. The suggestions listed below are based on the ideas you have been learning about throughout this topic. Your home energy audit could involve one or more of these.

KEY IDEA

A home energy audit could involve:

- a time-use survey of the number of hours spent in the home by each occupant, the activities they spend their time on and an assessment of how they are using energy during those times
- a study of water use in the home, identifying problematic areas where water may be lost through evaporation, and the flow rate of water when all taps are turned off — which should be zero, but may not be!
- a review of appliances that use gas, and the age of those appliances (because they become less efficient towards the end of their working life) combined with research into whether new electrical appliances would be a more efficient option
- a survey of the architectural features of the home that assist with temperature regulation, identifying opportunities to improve the thermal efficiency of the building by retrofitting new components or changing the way the occupants interact with the existing construction
- making a list of the appliances in use around the house and their Energy Rating, as well as a comparison to other models currently available (especially for those appliances known to be older and in need of replacement)
- cataloguing individual appliances and/or lights in the home, including a power rating and estimated or measured number of hours used per week for each device (which you should be able to combine to find a rate of energy consumption in kWh)
- an exploration of the opportunities that exist within your home to incorporate sensors into a smart home network, justifying your choices by explaining how each component would help improve efficiency.

ACTIVITY: Energy use comparison

Task

Ernesto wants to figure out which appliances in his home are using the most energy. Help him compare some common household devices based on their energy ratings.

Appliances to compare

- Fridge: Power rating of 180 W, used 24 hours a day
- Microwave: Power rating of 1.2 kW (1200 W), used for about 10 minutes a day
- Ceiling fan: Power rating of 75 W, used for about 8 hours a day
- Laptop charger: Power rating of 45 W, used for about 4 hours a day

Steps

1. Convert all power ratings to watts if needed (e.g. multiply by 1000 if in kW).
2. Convert all times into seconds if needed (e.g. multiply by 60 if in minutes).
3. Calculate the daily and weekly energy usage for each appliance (Energy = Power × Time). These values will be in joules (J).
4. Compare the daily and weekly energy use of each appliance.
5. Discuss which appliances are using the most energy and why.

Discussion questions

- Which appliance uses the most energy in Ernesto's home? Why?
- How do the patterns of use (time and frequency) affect total energy consumption?
- What could Ernesto do to reduce his household's energy use? Are there any behaviours or habits he could change?

Extension

- Look up the energy star ratings for similar appliances in your home. Are they high or low? What changes could your family make to improve energy efficiency?
- Consider how new technologies, such as smart plugs or energy-monitoring apps, could help track and reduce energy use.

Reflection

- How does understanding appliance ratings and energy consumption help us make better choices for our homes and the environment?
- How can this knowledge be applied to school or community projects about sustainability?

Presenting the data

Once you have made your observations and measurements, you will need to think about how the results can be presented. This will assist with drawing conclusions from the data, and allow you and your classmates to compare your findings.

A scientific poster, digital slideshow or written report would all be suitable formats for your presentation. The class could share their discoveries with each other, and perhaps invite other members of the school community to visit and review their findings.

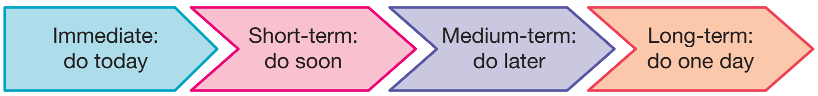
Where quantitative (numerical) data has been collected, one or more graphs of suitable types (such as bar, column or pie charts) may be a good way to display the results. Remember that a table of data should also be included. Qualitative data that cannot be displayed in the form of a graph may require more creativity. A gallery of annotated photographs could be used to showcase energy-saving features of the home, or you might include a numbered list of key observations.

Drawing a conclusion

A home energy audit will be most useful when it can identify specific energy-saving actions that could be taken. While it makes sense to prioritise the areas where your data shows the greatest opportunity to save energy, it is also worth considering how quickly you could implement change — and how realistic it might be for that change to occur. Anything that requires physical modification of the home or complete replacement of appliances may be expensive or impractical. Smaller changes that only require occupants of the home to commit to modifying their behaviours could be more realistic goals.

Setting out a timeline of actions (immediate, short-term, medium-term, long-term) can be an effective way of ensuring that the findings of the audit are put to good use while allowing adequate time for the household to plan and prepare before implementing the more significant changes.

FIGURE 9.24 An example of a timeline of actions



SCIENCE INQUIRY: Home energy audit

Aim

To collect data related to one or more selected aspects of the home's energy use, and identify specific actions that could be implemented to further improve energy efficiency

Task

Read back through the topic and identify areas relating to energy use that you think would be both interesting and practical to review in the context of your own home. Be realistic in your planning: you are unlikely to have the means or the time to measure everything there is to know about energy use in your home.

Determine how data will be collected. For consistency with the rest of the class, you may need to agree upon a methodology. Alternatively, each student could plan and conduct their own audit, potentially reviewing a wide range of different ways in which energy is used or misused in the home.

When the inquiry is complete, all students should return with their findings and share their conclusions.

After completion of the audit, you are encouraged to take energy-saving actions within your home, at school and in the wider community.

FIGURE 9.25 Conducting a home energy audit is an effective way to identify energy inefficiencies and explore solutions for reducing consumption and costs.

Scientific methods, conclusions and claims can be analysed to identify assumptions, possible sources of error, conflicting evidence and unanswered questions (VC2S8I06)

DISCUSSION

As a class discuss the following.

1. How does your home's design affect its energy efficiency? What changes could be made to improve it?
2. What are the environmental impacts of using hardwood versus softwood in home construction?
3. How can modern technology, such as smart meters and automated home systems, help improve energy efficiency?

9.5 Activities

learnon

9.5 Quick quiz on	9.5 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 3, 4	5, 6, 8	2, 7, 9

Remember and understand

1. **List** five possible energy-saving measures that could have been identified by a student who has conducted a home energy audit.
2. In terms of their effects on the power supply to your home, **state** the difference between a blackout and a brownout.
3. **Identify** which amount of energy is larger: 3 kWh or 10 MJ?
4. MC Comparing qualitative and quantitative data, which statement is most correct?
   A. Only quantitative data is useful for drawing a conclusion.
   B. Qualitative data will always be presented with a unit of measurement.
   C. An energy use in kWh is an example of a qualitative measurement.
   D. Quantitative and qualitative data can both be useful in scientific investigations.

Apply and analyse

5. **Suggest** four factors that could lead to a household having a water usage that is higher than average.
6. **Discuss** why kWh is a more appropriate unit for electricity bills, while gas bills are still metered in the standard scientific units of joules. Hint: what can be measured in kW, and what is measured in hours?
7. SI **Explain** why saving water is also a way of saving energy. You may need to conduct some additional research, or develop a set of key questions to ask your teacher in order to find out why delivering water to your home requires an energy input.

Evaluate and create

8. SI **Describe** how critical infrastructure in your community could be affected by a sudden loss of power, and justify the use of load shedding when the electricity supply is limited by factors such as extreme weather and high demand.
9. **Outline** one potential methodology for a student conducting a home energy audit. Ensure you include a list of required materials and detail the steps that need to be taken to collect the data.

Answers and sample responses are available in your digital formats.

LESSON 9.6 Review

9.6 Success criteria

(Green: I understand; Yellow: I can do it with help; Red: I do not understand)

Lesson	Success criteria	Green	Yellow	Red
9.2	I can distinguish between renewable and non-renewable resources.			
	I can evaluate the sustainable use of different resources.			
	I can compare the benefits and risks of resource extraction and energy production.			
9.3	I can identify heat and light as different forms of energy.			
	I can recognise that energy transfers via conduction, convection and radiation can be analysed in terms of energy efficiency.			
	I can explain how household energy consumption is affected by building design, season and climate, relative to the positions of the Earth and Sun to the seasons.			
9.4	I can relate appliance choice to household energy consumption.			
	I can discuss considerations (ethical, environmental, social and economic) related to energy transfers and transformations in homes.			
9.5	I can represent energy transfers and transformations in a simple system.			
	I can undertake a household energy audit.			
	I can propose ways to decrease energy consumption.			

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Post-test	Topic 9 Post-test
eWorkbook	Topic 9 eWorkbook
Digital document	Key terms glossary

9.6 Activities

learnon

9.6 Review questions

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 4, 7, 8	5, 6, 9, 10, 11, 12, 14, 15	13, 16, 17, 18, 19, 20

Remember and understand

1. **List** three renewable and three non-renewable materials regularly used in and around your home.
2. **Recall** the types of construction materials that can act as carbon sinks.
3. **Identify** the types of energy most commonly produced as waste by inefficient processes. It may help to think of a specific process, such as carrying panels of roof material up to the top of a building and fixing them into place.
4. **List** the inputs (including both materials and energy) needed to make a section of wall for a typical residential dwelling.
5. **Suggest** four reasons why installing a photovoltaic solar panel causes carbon dioxide emissions.
6. **Explain** why appliance Energy Ratings are an open-ended scale (i.e. with possible ratings exceeding five stars).
7. **State** the reasons that wide, overhanging roof eaves help regulate the temperature of a building in summer and in winter.
8. **Outline** factors that could lead to a household having an electricity usage that is higher than average.
9. **Recommend** energy-saving measures that would benefit a typical household, that is, the sorts of things that might be identified by a home energy audit.

Apply and analyse

10. The SI units are the scientific standard, and they are preferred for most measurements — unless another unit is situationally more useful or appropriate. For example, gas bills usually measure the amount of energy in megajoules (MJ), a simple multiple of the base SI unit for energy, the joule.
    a. How many J are there in one MJ?
    b. **Suggest** a reason for billing in MJ rather than J.
    c. **Explain** why electricity bills are instead metered in kilowatt-hours (kWh).
11. **Discuss** why any system that transports and delivers water to homes is likely to have an efficiency of less than 100 per cent.
12. Efficiency values are limited to a range of numbers between 0 and 100 per cent. **Justify** why these values are the theoretical limits for any real system.

Use the following information to answer questions 13 and 14.

A study of homes in Australia and New Zealand, published in 2022, calculated the amount of energy used across five categories: heating and cooling the building (which typically accounted for 41 per cent of the total used), running all other appliances not used for heating or cooking (25 per cent), heating water (23 per cent), cooking (6 per cent) and lighting the home (5 per cent).

13. SI The occupants of a typical home wish to improve its energy efficiency. They find out that two energy-saving programs are available in their area. Both involve replacing technologies in the home with high-efficiency models. One option is to replace all gas-burning appliances with electrically operated devices (degasification). The other is to replace all the light bulbs.
    Analyse the data provided above to determine which option would likely have the greatest impact, and **infer** which option would be the cheapest to implement.

14. **SI** In their design for a single-storey home, architects have introduced three features that improve the comfort and energy efficiency of the home. Using the data above, rank these features in order of how effective at saving energy they are likely to be.
   i. Wide eaves, shading the windows to reduce direct sunlight during the summer months
   ii. North-facing windows, to capture low-angle sunlight that will provide warmth and light in winter
   iii. A rooftop solar hot water service, which pre-heats water and reduces the cost of taking a shower
15. Adding a large, wall-mounted rechargeable battery pack to a house that already has a solar (photovoltaic) installation on the roof is one way to increase energy efficiency. **Explain** how the addition of the battery makes the home more energy efficient.
16. Accounting for our geographical location relative to the equator, **explain** why the orientation of a building (and especially its windows) will have an impact on its internal temperature in summertime.
17. **Suggest** three ways to improve the thermal efficiency of a newly designed (but not yet constructed) multistorey residential building.
18. **Name** the type of wind conditions that typically lead to hot, dry, cloudless days during Victoria's summer months. What impact do these conditions have on (i) overnight temperatures and (ii) solar power production?

Evaluate and create

19. **SI** Create an inventory of materials used to construct and fit out your school classroom. This will be limited to things you can recognise (or imagine being used) but there should be plenty for you to discover! Consider furniture and cabinetry, including fittings such as doors, sinks, handles and taps; surface treatments and materials used for ceilings, flooring and walls; and electrical devices, including heating and lighting.
    Using a table or Venn diagram, sort the materials according to whether they are renewable or non-renewable, as well as whether you believe they are abundant or scarce in Australia. For example, fresh water might be classified as a naturally occurring resource that is scarce (but also renewable).
20. **SI** Write a letter to the landlord of a rental property, or the body corporate responsible for managing a small apartment block, describing the results of a recent energy audit. Note: this is a creative writing task so you will need to be imaginative when coming up a description of the audit's methodology, findings and recommendations.

Answers and sample responses are available in your digital formats.

on To test your understanding and knowledge of this topic, go to your learnON title at www.jacplus.com.au and complete the **post-test**.

10 Electrical circuits

CONTENT DESCRIPTION

Electrical circuits transfer energy when current flows and can be designed for diverse purposes using different components; the operation of circuits can be explained using the concepts of voltage and current (VC2S8U17)

Source: Victorian Curriculum F–10 Version 2.0

LESSON SEQUENCE

LESSON 10.1 Overview

10.1.1 Introduction

Electricity is an important part of everyday life. Nearly everything you use from waking up in the morning to going to bed at night relies on electricity, including kitchen appliances, heating and cooling, cooking, entertainment and security. Many of these devices rely on sensors that turn devices on or off. An oven relies on a temperature sensor to keep the cooking temperature constant, a security light uses motion sensors to detect people and a street light uses light sensors to know when it has become dark enough to turn on. All these devices use electrical circuits to manipulate electricity in similar ways.

FIGURE 10.1 The device shown contains a temperature sensor, air pressure sensor and humidity sensor, which provide information about the environment in the room. These types of sensors are becoming common in homes, schools, offices, farms and factories to help people feel comfortable, and to make sure plants and animals grow well and industrial processes are efficient.

DISCUSSION

- What actually moves when electrical current flows?
- What is the difference between current and voltage?
- Why do the rest of the lights in your house stay on when one light globe stops working?
- How many household appliances can you name that rely on a sensor?
- Can you explain how a heater works? How does it know when to turn on and off?
- What is an LED and how is it different from an incandescent light globe?
- Why do you need a safety switch as well as fuses or circuit breakers in your electricity meter box?
- Why is it dangerous to use many electrical appliances in the wet or near water?

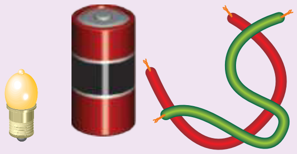
SCIENCE INQUIRY: Making the right connections

Aim

To connect a battery to a light globe so that it lights up

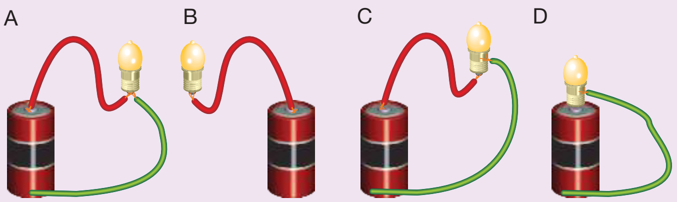
Materials

- 2.5-V torch light globe
- 1.5-V battery
- two connecting leads



Method

1. Connect one or two leads, a 2.5-V light globe and a 1.5-V battery to make the globe light up.
2. Try the different arrangements as shown in figures A, B, C and D to see whether there is more than one way to make the globe light up.



3. Experiment with different arrangements to find other ways to make the globe light up.

Results

1. Identify which of the electric circuits shown have the components correctly arranged so that the light globe works.
2. Use a diagram to describe any other arrangements that cause the globe to light up.

Discussion

1. Draw a flow diagram to show the energy transformations that occur when the globe lights up.
2. Determine whether all the energy transformations are useful and explain your reasoning.

Conclusion

Summarise the findings of this investigation about creating electric circuits.

Equipment can be selected and used to generate and record data with attention to precision, using digital tools as appropriate (VC2S8I03)

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Pre-test	Topic 10 Pre-test
eWorkbooks	Topic 10 eWorkbook Student learning matrix
Practical investigation eLogbook	Topic 10 Practical investigation eLogbook
Digital document	Key terms glossary

LESSON 10.2 Electrical current, voltage and resistance

LEARNING INTENTION

In this lesson you will:
- define electrical charge, current, voltage and resistance and explain the role of each in an electrical circuit
- understand how energy is transferred and transformed in an electrical circuit.

10.2.1 Electrical charge

Atoms contain three different types of charged particle:
- the **proton**, which is positively charged
- the **neutron**, which is neutral
- the **electron**, which is negatively charged.

The proton and neutron are found in the **nucleus** and cannot move away from the nucleus. They are fixed in place. Electrons are found in the space around the nucleus and are able to move around the nucleus. Electrons are also able to leave the atom and travel independently.

Electrical energy is carried by electrons because the electrons are not held in one place or attached to one atom. They can move freely.

10.2.2 Electric currents

The flow of **electric charge** is called **electric current**.
- An electric current is a measure of the amount of electric charge passing a particular point in an electric circuit every second.
- The unit of current is the ampere (A) or amp for short.

The electric current in wires and most electrical devices is caused by the flow of negatively charged electrons. This is normally called the 'electron flow'. However, for historical reasons, the electric current is said to flow through the circuit from the positive terminal of the **power supply** to the negative terminal and is often thought of as a flow of positive charge. This is normally called the 'conventional current' or just the 'current'.

Electric current can only flow if there is a complete path for it to travel along. As the name suggests, an **electric circuit** is a path that ends up back at its beginning with no breaks or gaps. If there is a gap in a wire, or a **switch** that is open, no electric current will flow anywhere in the circuit.

While electrical energy appears to move extremely quickly around a circuit because a light turns on as soon as the switch is activated, electrical charges actually move quite slowly around an electrical circuit.

10.2.3 Voltage

Voltage is the amount of electrical potential energy given to electrons by a battery, power supply or power point.

Electrons transfer all of this energy to the different **components** of an electric circuit. All the electrical potential energy, or voltage, supplied by the power supply is used up before the electrons return to the power supply.

The electrical potential energy used up in each component is also known as the **potential difference** or the voltage drop, because it is the change in potential (stored) energy of the electrons as they move through the component.

Different batteries and power supplies provide different amounts of electric potential energy to the electrons. A 6-V battery provides more electrical potential energy to electrons than a 1.5-V battery. This means the components of an electric circuit connected to a 6-V battery receive more energy than the components of an electric circuit connected to a 1.5-V battery. The power points in your home and school provide 230 V of electrical potential energy to electrons.

10.2.4 Resistors and transducers

The components of an electric circuit that are energy converters (**transducers**) are called resistors. A resistor **transforms** the electrical potential energy carried by the electric charges into other forms of energy, both useful and non-useful, such as light, heat, sound and movement. In old-fashioned incandescent light globes, the resistor is the **filament** (figure 10.2), a coiled tungsten wire inside the light globe. The filament glows brightly when it gets hot and transforms electrical energy into light (and thermal) energy. In a hairdryer, there are two resistors: a heater and a fan motor. The heater transforms electrical potential energy into thermal energy, while the fan motor transforms the electrical potential energy into kinetic (and thermal) energy.

All resistors 'push back' against the power supply. This is called **resistance**. The greater the resistance, the less current can flow in the circuit.

FIGURE 10.2 A filament in a light globe

FIGURE 10.3 Resistance is like a constriction or obstruction that hinders the flow of water. Higher resistance means it is more difficult for the current to flow through the circuit. If the current is kept constant, the voltage (water pressure) is increased.

Imagine you are at a party with a group of friends. You all need to leave but, to do so, you have to push your way through a crowd of people. They are all dancing and keep getting in your way. Sometimes they bump into you. It slows you down and you need to use energy to get past them. If you stop, you will be pushed by the people behind you and be made to move again. Near the exit is a corridor full of people dancing. You squeeze through but, with reduced space, you are pushed around more than ever and use up even more energy to get through the corridor! This is very similar to the way electrons travel through circuits.

The negatively charged electrons moving in an electric circuit have to make their way past the atoms in the connecting leads and resistors that make up the circuit. The atoms are constantly vibrating, and collisions between electron and atom are common. Electrical resistance is a measure of how difficult it is for electrons to flow through each part of a circuit. The resistance to the flow of electric charge limits the electric current, just as the resistance of a narrow and crowded corridor limits the number of people that can pass through in a given time interval. Electrical resistance also determines how much electrical potential energy is lost by electric charge, the voltage drop, as the electrons move through a circuit.

Different materials influence resistance in circuits:

- **Electrical conductors** have relatively little resistance. They allow large electric currents to flow with little loss of energy.
- **Electrical insulators** have a relatively large electrical resistance. They allow very little electric current to flow.

The unit of resistance is the ohm (Ω).

INVESTIGATION 10.1

Making a model kettle

Aim

To make a model kettle and investigate the effect of voltage on its function

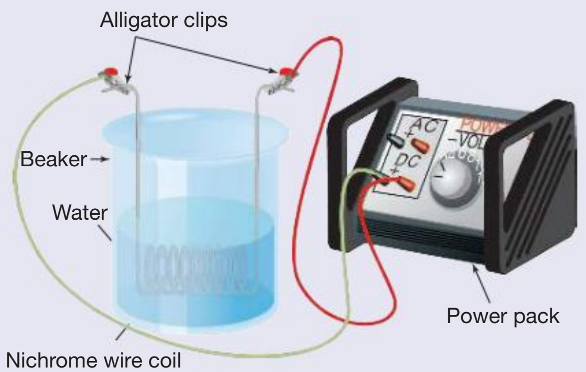
Materials

- 100-mL beaker
- wires with alligator clips attached
- power supply with different voltage options
- length of nichrome wire
- thermometer
- glass stirring rod
- measuring cylinder
- pencil

Method

1. Refer to figure 10.4 to make your electric kettle model.
   Tip: Wind the nichrome wire around the pencil to make your coil. Make sure individual loops do not touch one another.

FIGURE 10.4 This electric circuit is a model of an electric kettle. The wire coil, or the loading coil, will heat up when electrical energy is passed through it.



2. Ask a member from another group to check your circuit. Then ask your teacher to check it.
3. Use the measuring cylinder to add 50 mL of water to your beaker. Make sure that the coils in the nichrome wire are well covered. Make sure that you have accurately measured how much water you used.
4. Place the stirring rod in the beaker and gently stir the water. Be careful not to damage the wire coil.
5. Use the thermometer to record the temperature of the water.
6. Set the power supply to 6 V and turn it on. Heat the water for about 10–15 minutes. Gently stir the water during this time.
7. When the time is up, switch off the power supply and record the new temperature.
8. Empty out the water and then repeat steps 3–7, but with the power supply on 12 V. Make sure that you use the same volume of water and that you measure the final temperature after the same amount of time.

Results

Record your results in a table like the one shown.

Trial	Voltage used (V)	Initial temperature (°C)	Final temperature (°C)	Temperature increase (°C)
1	6			
2	12			

Volume of water used:
Time circuit was switched on for:
Other observations:

Discussion

1. Why was the same volume of water used in each trial?
2. Why was the same time used in each trial?
3. Was there a difference between the two temperature increases? Explain what you observed.
4. If the experiment was repeated with the power supply set to 3 V, predict the final temperature of the water. Justify your prediction.
5. If the experiment was repeated with a shorter piece of nichrome wire with a lower resistance, predict the final temperature of the water. Justify your prediction.
6. The voltage used for Trial 2 was exactly double the voltage used for Trial 1. Did the temperature difference double? Explain your observation.

Conclusion

Summarise the findings for this investigation.

ACTIVITY: PhET simulation

Access the **PhET simulation: Ohm's Law** and **Resistance in a wire** interactivities in the Resources panel.

10.2 Activities

learnon

10.2 Quick quiz on | **10.2 Exercise**

LEVEL 1	LEVEL 2	LEVEL 3
2, 3, 5, 6	1, 4, 7	8, 9, 10, 11, 12

Remember and understand

1. **Describe** how the voltage of a power supply influences the energy provided to components in an electric circuit.
2. MC Which of the following correctly describes electric current and voltage?
   A. Electric current is a measure of the amount of energy passing a particular point in an electric circuit every second; voltage is a measure of the amount of electrons gained or lost by the power supply.
   B. Electric current is a measure of the amount of electric charge passing a particular point in an electric circuit every second; voltage is a measure of the amount of electrical energy in the power supply.
   C. Electric current is a measure of the amount of electric charge in the power supply; voltage is a measure of the amount of electrical energy gained or lost by electric charge as it moves through the circuit.
   D. Electric current is a measure of the amount of electric charge passing a particular point in an electric circuit every second; voltage is a measure of the amount of electrical energy gained or lost by electric charge as it moves through the circuit.

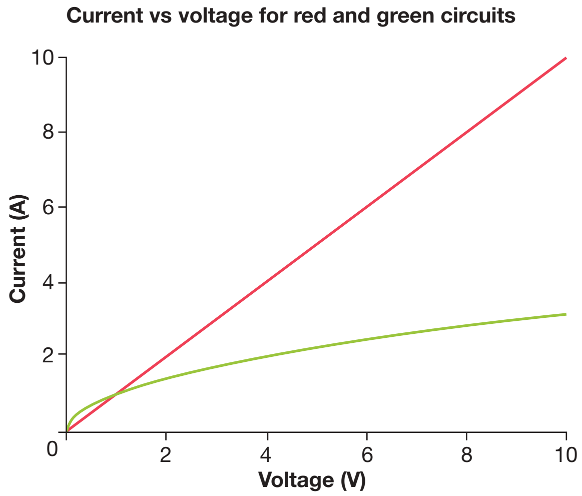
3. Some torches use three 1.5-V batteries. **Calculate** the total voltage of such torches.
4. **Explain** why voltage drop is also known as potential difference.
5. **Explain** why connecting wires are usually made of copper.
6. **Define** the following terms.
   a. transducer
   b. resistor
   c. voltage
   d. electric current

Apply and analyse

7. **Compare** the movement of electrical potential energy in a lightning bolt to electric current in an electric circuit.
8. **Identify** three different resistors that transform electrical potential energy into:
   a. kinetic energy
   b. thermal (heat) energy
   c. light energy
   d. sound energy
9. **Describe** the relationship between resistance and electric current.

Evaluate and create

10. You have access to some paper straws, some chewing gum, an elastic band, some paper clips and a graphite pencil. Which objects could you use to create an electric circuit?
11. SI Benjamin Franklin was one of the first physicists to study electricity and electric current. Research his 'kite and key' experiment and **explain** what he discovered using the terms voltage, current and resistance.
12. SI Look at the following graph showing current on the *y*-axis and voltage on the *x*-axis.



   a. **Describe** the relationship between current and voltage for the red line.
   b. **Describe** the relationship between current and voltage for the green line.
   c. If both circuits were connected to the same battery, which circuit (red or green) would have the higher current flowing through it? **Explain** your answer.
   d. If both circuits had the same current flowing through them, which circuit (red or green) would be connected to the battery with the larger voltage? **Explain** your answer.

Answers and sample responses are available in your digital formats.

LESSON 10.3 Series and parallel circuits

LEARNING INTENTION

In this lesson you will:
- identify series and parallel circuits and describe the differences between them
- predict the behaviour of current and voltage in both types of circuits.

10.3.1 Electrical circuits

All electric circuits consist of three essential items:
- a power supply to provide the electrical energy
- a resistor (or resistors) in which electrical energy is converted into other useful forms of energy
- a **conducting path** that allows electric charge to flow around the circuit.

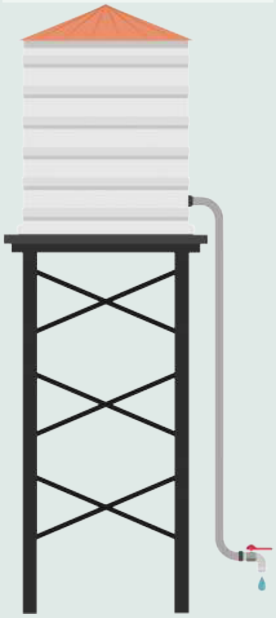
The electrical energy provided by batteries and power outlets is transformed into other forms of energy *only* when the conducting path is complete, which allows electric charge to flow through the circuit.

Conducting paths have the following features.
- Any kind of break in the path, such as a broken wire or burned-out component, will stop the current flowing.
- A deliberate break in a circuit can be made using a switch. This allows you to have control over whether or not the conducting path is complete.
- Most of the electrical energy provided by the power supply is transformed in the resistors. Some electrical potential energy is transformed into heat by the conducting path, but only a minimal amount.
- The conducting paths in the electric circuits in appliances are usually made of metals such as copper so that they have little resistance to the flow of electric charge.

EXTENSION: Water analogy

The water/hose analogy is a useful way to explain the difference between voltage, current and resistance in an electric circuit. Imagine you have a hose connected to a water tank.
- **Voltage** is like the water pressure in the hose. It represents the force or 'push' that causes the water to flow. Higher water pressure corresponds to a higher voltage, which leads to a stronger flow.
- **Current** is like the flow rate of water through the hose. The current is equivalent to the volume of water flowing through the hose per second.
- **Charge** is like the amount of water stored in the tank. The more water there is in the tank, the more charge there is in the circuit.
- **Resistance** is another factor affecting flow in a circuit (see lesson 10.4). Resistance is like a constriction or obstruction of the hose that restricts the flow of water. Higher resistance means it is more difficult for the water to flow through the hose.

FIGURE 10.5 A water analogy can be used to better understand voltage, current, charge and resistance in electrical circuits.



INVESTIGATION 10.2

Switched-on circuits

Aim

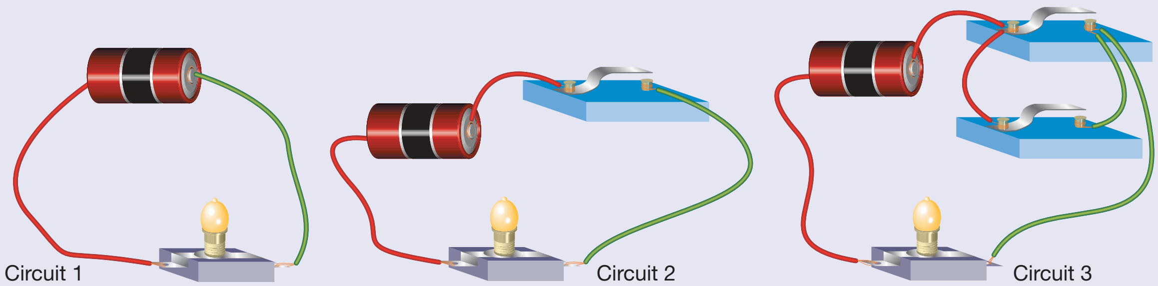
To compare the effect of a single switch with two switches

Materials

- 2.5-V globe and holder
- 1.5-V battery and holder
- 5 connecting leads with alligator clips or banana plugs
- 2 tapping switches

Method

1. Connect circuit 1 as shown.
2. Connect circuit 2 as shown.
3. Close the switch.
4. If nothing happens, open the switch, check that your circuit is connected properly and try again. If nothing happens this time, replace the globe.
5. Add a second switch as shown in circuit 3.
6. Close each switch individually and both at the same time. Record your observations.



Discussion

Circuit 1

1. How can you stop the globe in circuit 1 from glowing?

Circuit 2

2. Describe what happens to the globe in circuit 2 when the switch is closed.
3. Explain, using the terms current and voltage, what is happening in the electric circuit when the switch is closed.

Circuit 3

4. Describe what happens to the light globe in circuit 3 when:
   a. neither of the switches is closed
   b. either one of the switches is closed
   c. both of the switches are closed.
5. Explain your observations using the words circuit, current, voltage, energy and resistance.

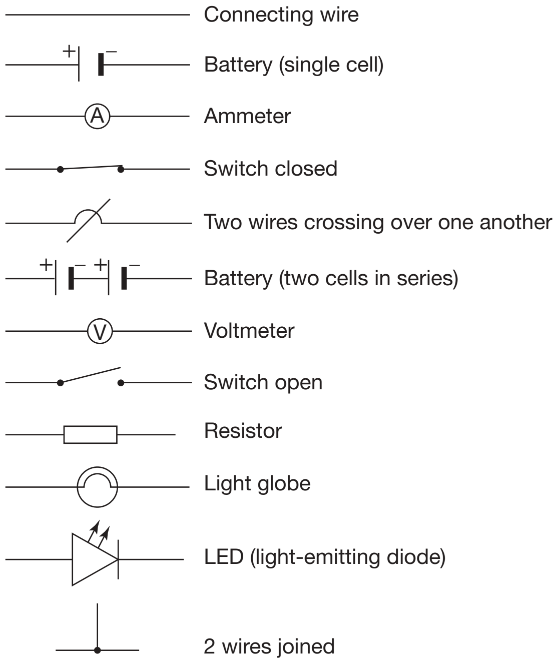
Conclusion

What can you conclude about electric circuits and the role of switches in electric circuits.

10.3.2 Circuit diagrams

Diagrams of electric circuits need to be drawn in a way that can be interpreted by people all over the world. These diagrams are called **circuit diagrams**. Circuit diagrams use straight lines for connecting leads and symbols for other parts of circuits.

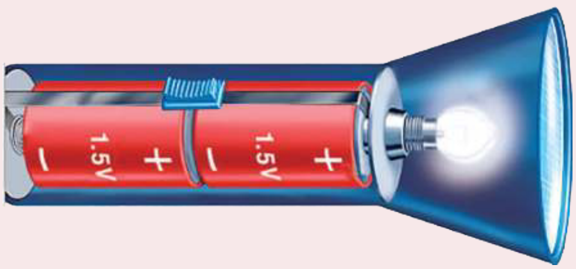
FIGURE 10.6 Some circuit diagram symbols



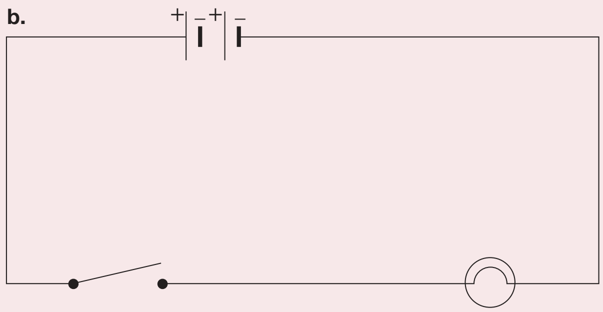
SCIENCE AS A HUMAN ENDEAVOUR: Circuit diagram of a torch with an incandescent globe

FIGURE 10.7 **a.** Components of a torch **b.** Circuit diagram for a torch

a.



b.



Features of the torch circuit:

- The power supply of a torch usually consists of two or more 1.5-V batteries connected in series. When two 1.5-V batteries are connected in series, the total supplied voltage is 3.0 V. Twice as much electrical potential energy is available for the electric charges (electrons) to transport around the circuit.
- The resistor in a torch circuit is the light globe or an LED (light-emitting diode).
- When the switch is closed, electric current flows around the circuit.

- As electric charge passes through the light globe, the electric potential energy is transformed into heat in the filament. The filament is the coiled wire inside the light globe. The filament is made of the metal tungsten and glows brightly when it gets hot. In an LED torch, almost all of the electrical potential energy is transformed directly to light by a different type of resistor called a diode.
- The conducting path consists of a conducting wire, the switch and an incandescent light globe or LED.

1. What is the total voltage of a torch circuit when two 1.5-V batteries are connected in series?
2. Compare the energy transformations in an incandescent torch globe and an LED torch.
3. Describe the role of the filament in an incandescent globe and explain why tungsten is used.
4. Why is an LED more energy efficient than an incandescent globe?
5. What would happen if the conducting path in the circuit was broken?

Scientific knowledge, including models and theories, can change because of new evidence (VC2S8H01)

10.3.3 Series and parallel circuits

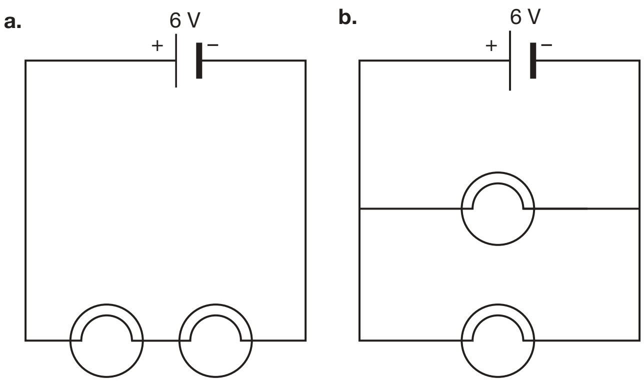
The parts of the torch circuit shown in figure 10.7 — the batteries, the switch and the globe — were all connected one after the other. This type of circuit is a **series circuit**. Series circuits are usually easy to connect. However, if any one part of the circuit is faulty, the connecting path is broken and nothing in the circuit will work. For example, if the Christmas tree lights in figure 10.8 were connected in **series**, a single faulty light globe would cause all of the light globes to stop glowing.

In a **parallel circuit**, each component is connected in a separate conducting path. This means if one part of the circuit is faulty, the other parts will still work. Adding extra pathways also allows more current to flow from the power supply, effectively lowering the resistance. This drains batteries more quickly, but means that all resistors can work at full power.

If the Christmas tree lights shown in figure 10.8 were connected in parallel, and one light globe was faulty, the other light globes would still glow. Their conducting paths would not be affected.

FIGURE 10.8 Parallel wiring keeps Christmas tree lights glowing even if one bulb fails.

FIGURE 10.9 a. Series circuit **b.** Parallel circuit



SCIENCE INQUIRY: Series and parallel circuits

Electrical circuits can be arranged in series or parallel configurations, each with distinct characteristics. In a series circuit, components are connected end-to-end, forming a single path for current flow. In a parallel circuit, components are connected across multiple paths, allowing current to flow through more than one pathway.

Series circuits share the same current through all components, but the voltage is divided among them. Parallel circuits, on the other hand, maintain the same voltage across each pathway, while the total current is shared among the branches. These distinctions influence how circuits behave in real-world applications.

In series circuits, adding more components increases total resistance and reduces current, which may cause devices to function less effectively. In parallel circuits, adding more branches allows current to flow more easily, often maintaining consistent device performance.

Key features are listed as follows.

- Series circuits: single current path, divided voltage, increased resistance with more components
- Parallel circuits: multiple current paths, consistent voltage, decreased total resistance with additional branches

Understanding the differences between series and parallel circuits is essential for designing effective electrical systems. Patterns of current and voltage behaviour in these configurations inform choices in practical applications such as household wiring and electronic devices.

1. Why does adding more components in a series circuit reduce the current?
2. How does adding additional branches in a parallel circuit affect the total resistance?
3. Which type of circuit is better suited for household wiring and why?
4. If a light globe in a parallel circuit stops working, what happens to the other globes?
5. Draw a labelled diagram of both a series and parallel circuit, showing the flow of current and distribution of voltage.

Information and processed data can be analysed to show patterns, trends and relationships, and to identify anomalies (VC2S8I05)

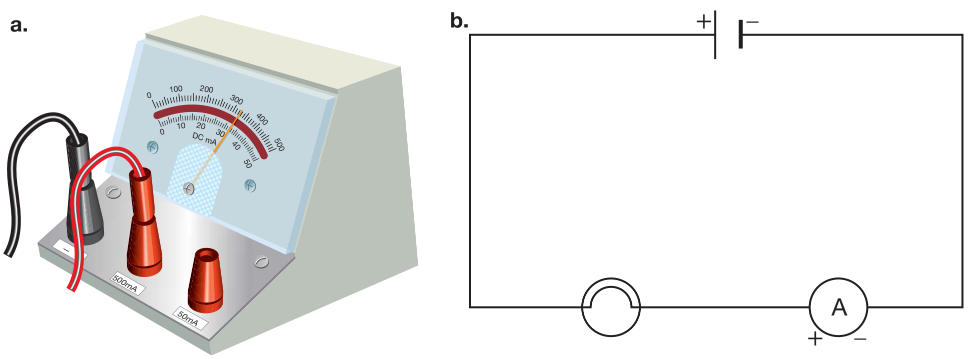
10.3.4 Ammeters

Like the currents of water in rivers and the sea, electric current can be measured.

Water currents in a river or the sea can be measured by determining the amount of water that passes a particular point every second. Likewise, the size of the electric current in an electric circuit can be measured by finding the amount of electric charge passing a particular point in an electric circuit every second.

An **ammeter** is used to measure the size of electric current flowing in an electric circuit. An ammeter measures electric current in amperes (A) or in one-thousandths of an ampere, which are called milliamperes (mA).

FIGURE 10.10 a. An ammeter is used to measure electric current. **b.** Circuit diagram showing how an ammeter is used to measure the electric current through a light globe

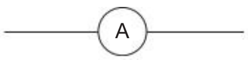


Most ammeters have two positive terminals. This allows the ammeter to provide readings over a large range of currents. There is always one scale per positive terminal. Make sure you are using the scale that corresponds to the positive terminal you have plugged in.

Using an ammeter

Most ammeters used in school laboratories have one (black) negative terminal and two or more (red) positive terminals. The following points are important when using ammeters. Refer to them whenever using ammeters in an investigation.

- The positive terminal of the ammeter should always be connected in series so that it is closer to the positive terminal of the power supply than the negative terminal of the power supply.
- Use the positive terminal with the highest value first. If the measured current in your circuit is smaller than the value shown on one of the other terminals, you may change the connection to the positive terminal with the smaller value.
- The scale has at least two sets of numbers on it. Use the set that matches the connected positive terminal. To check you are using the correct scale, look at the largest number on the scale and it match to the information below your chosen positive terminal.
- An ammeter is represented by the symbol:

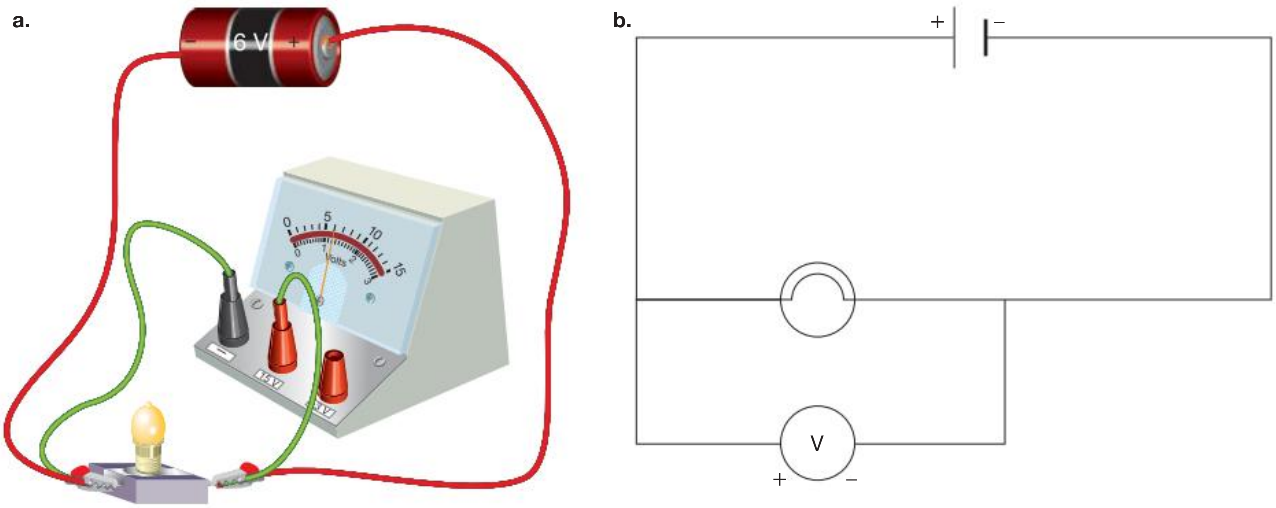


- Always read an ammeter from directly in front. The error obtained by not reading from directly in front is called a **parallax error**.
- Ammeters are easily damaged. If the current reading is off the scale, switch the circuit off immediately.

10.3.5 Voltmeters

A **voltmeter** is used to measure the voltage gain across the terminals of a power supply or voltage drop across parts of an electric circuit. Voltage is measured in volts (V).

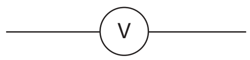
FIGURE 10.11 a. A voltmeter is used to measure the voltage gain or drop across two parts of an electric circuit. This voltmeter is being used to measure the voltage across a light globe. **b.** Circuit diagram showing how a voltmeter is used to measure the voltage drop across a light globe



Using a voltmeter

Like ammeters, most voltmeters used in school laboratories have one (black) negative terminal and two or more (red) positive terminals. Remember the following points when using voltmeters.

- A voltmeter should be connected in parallel with the part of the circuit across which the voltage is being measured. The positive terminal should always be connected so that it is closer to the positive terminal of the power supply than the negative terminal of the power supply. (If the arrow on the voltmeter goes off the scale to the left, you have connected your positive and negative terminals the wrong way around. Fix this by disconnecting the wires from the voltmeter and connect them the opposite way around.)
- Use the positive terminal with the highest value first. If the measured voltage in the circuit is smaller than the value shown on one of the other terminals, you may change the connection to the positive terminal with the smaller value.
- The scale has at least two sets of numbers on it. Use the set that matches the connected positive terminal.
- A voltmeter is represented by the symbol:



- Always read a voltmeter from directly in front to avoid parallax error.

10.3.6 Precision and uncertainty in measurements

Types of errors and how to avoid them

When you are reading scales such as those on a ruler, a mercury or alcohol thermometer, or an ammeter or a voltmeter, you always have to make an estimate. The pointer almost never points directly to a number or marking. Having to estimate the reading introduces uncertainty into your result. The size of the uncertainty will depend on the size of the smallest subdivision shown on the scale. Generally, you should be able to read a scale to the nearest marking, making the uncertainty half of the smallest subdivision.

For example, on the 3-V scale of the voltmeter shown in figure 10.12 the smallest division is 0.1 V. With care, the scale can be read with an uncertainty of about 0.05 V. The needle is between the 2.3 marking and the 2.2 marking, so the voltage can be recorded as 2.25 V.

FIGURE 10.12 There is always a degree of uncertainty when reading a scale like this.

When doing experiments, there will also be errors associated with your results. Errors are different from uncertainties because they are not connected to estimation or 'guessing'. Errors have a range of causes, Often they happen because of problems with an experimental method, not following the experimental method properly, using the incorrect measuring equipment or using measuring equipment incorrectly.

Random errors

This type of error occurs due to small changes in the experiment that cannot be controlled. **Random errors** occur when measuring length because the start of the ruler or measuring tape will vary slightly. Random errors also occur when the quantity being measured changes randomly. For example, when the temperature of the water in a saucepan is being measured, it may increase or decrease slightly due to movement in the water. Random errors affect the **precision** of the measurement.

Systematic errors

Errors that are consistently high or low due to the incorrect use or limitations of equipment are called **systematic errors**. Parallax errors caused by consistently reading the scale of an ammeter or voltmeter from one side instead of directly in front are systematic errors. An incorrect zero reading when there is no current or voltage, or uneven scales, is also a systematic error. Systematic errors affect the **accuracy** of the measurement.

Reducing errors

Random errors can be reduced by repeating measurements numerous times and calculating an average. But this is not always possible or practical. Taking a very large number of measurements across the widest possible range of values is an alternative method for reducing the effect of random errors. However, such errors can never be totally eliminated. Some systematic errors can be eliminated by knowing how to use the equipment correctly. If a measuring instrument does not read zero when it should, the error can be eliminated by calibrating the equipment before use. But there will always be systematic errors, because no scale or measuring instrument is perfect. Drawing graphs with experimental results can help remove the effect of systematic errors.

INVESTIGATION 10.3

Probing a simple circuit

Aim

To investigate the current and voltage drops within an open and closed circuit

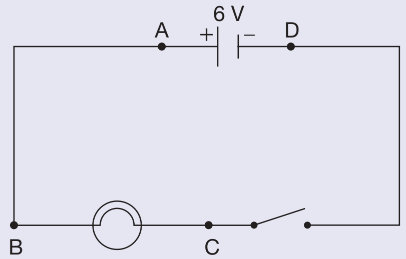
Materials

- power supply (set to 6 V)
- 6-V light globe and holder
- 6 connecting leads with alligator clips or banana plugs
- very long connecting lead (at least 2 m long)
- switch
- ammeter
- voltmeter

Method

Part A: Switch closed

1. Set up the circuit shown in the diagram. You should be able to set it up using only three connecting leads.
2. Use the ammeter to measure the electric current at each of the points A, B, C and D. Record your measurements in the table.



CAUTION: Check that the ammeter is connected properly before closing the switch. Ask your teacher if you are not sure.

3. Remove the ammeter from the circuit.
4. With the switch closed, use the voltmeter to measure the voltage drop across:
   a. the power supply (across points A and D)
   b. the light globe (across points B and C)
   c. the switch (across points C and D)
   d. one of the connecting leads (across points A and B).

Part B: Switch open

5. With the switch open, use the ammeter to measure the electric current at each of the points A, B, C and D.
   Before you connect the ammeter, make a prediction of the electric current at each of the four points.
6. With the switch open, use the voltmeter to measure the voltage drop across:
   a. the power supply (across points A and D)
   b. the light globe (across points B and C)
   c. the switch (across points C and D)
   d. one of the connecting leads (across points A and B).
   Before you connect the voltmeter, make a prediction of the voltage drop across each of the four items.

Results

	Using the ammeter		Using the voltmeter	
	Location in circuit	Electric current (mA)	Item	Voltage drop (V)
Switch closed	A		Power supply	
	B		Light globe	
	C		Switch	
	D		Connecting lead	
Switch open	A		Power supply	
	B		Light globe	
	C		Switch	
	D		Connecting lead	

Discussion

Part A: Switch closed

1. Is there any difference between the amount of current travelling through the points A, B, C and D?
2. How does the voltage drop across the terminals of the power supply compare with the voltage drop across the light globe when the switch is closed?
3. Where is most of the electrical energy supplied by the power supply used?

Part B: Switch open

4. Compare your predictions with your measurements. Discuss any similarities and differences.
5. Explain why the voltage drop across the open switch is different from the voltage drop across the closed switch. Include a definition of voltage drop in your response.
6. Compare the voltage drop across the light globe in the two circuits. Explain the similarities and differences.

Conclusion

Write a couple of sentences summarising the voltage and current measurements in circuits with open and closed switches.

10.3.7 Voltage and current in series and parallel circuits

The brightness of light globes in electric circuits depends on how quickly energy flows through the light globe. There are two factors that affect how quickly the energy flows:

- The amount of electrical potential energy the light globe transforms. The voltage drop across the light globe is a measure of this.
- The number of electrons passing through the light globe each second. The electric current passing through the light globe is a measure of this.

We can change the brightness of two bulbs by arranging them in series or parallel. We must first think about what happens to voltage and current in series and parallel circuits.

Series circuits

- Current is the same at all points in the circuit.
- Adding more light globes means resistance increases, so less current can flow in the circuit.
- The voltage of the supply must equal the sum of the voltage drops across the individual resistors. When more resistors are added, the voltage drop across each resistor will decrease.

Parallel circuits

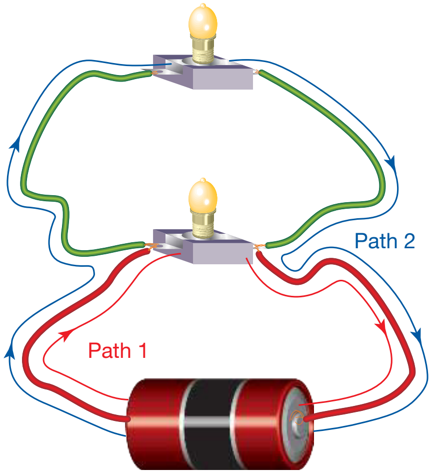
- Adding more current paths to the circuit lowers the resistance of the circuit.
- More current leaves the power supply.
- Current from the power supply splits into all branches and reunites when the wires reconnect.
- The voltage drop is the same across each loop of the circuit.

When using identical light globes, this means that:

- In a series circuit, the globes will have the same brightness but will become dimmer if more light globes are added. They have to share the electrical potential energy equally and all globes have the same electric current passing through them.
- In a parallel circuit, the globes will have the same brightness because each path in the circuit will have the same voltage drop across it. They equally share the electric current passing through the power supply.

The lights in your home are connected in parallel. Each light has the same voltage drop across it. Each electron gets the same amount of electrical potential energy from the power supply. But different light globes, bulbs and fluorescent tubes allow different amounts of electric current through, meaning the brightness of the lights can differ.

FIGURE 10.13 A parallel circuit has more than one conducting path.



DISCUSSION

If you had a bucket full of water but had a hole in the bottom, the weight of the water would provide the energy to push the water out; this is acting like the voltage. The water flowing per second is the current. What would happen to the voltage and current for this hole if a second hole (of the same size) was punched in the bottom of the bucket? How would the voltage and current compare between the holes now that there are two holes?

INVESTIGATION 10.4

Series and parallel circuits

Aim

To compare series and parallel circuits

Materials

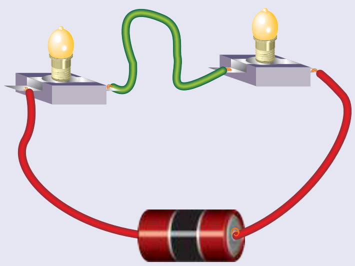
- three 2.5-V or 3.0-V torch globes
- 1.5-V battery
- 6 connecting leads

Method

Part A: Series circuits

1. Connect one light globe and the battery together with wire leads so that the light globe lights up.
2. Add a second light globe in series with the first light globe as shown in the diagram.
3. Remove one light globe from its holder.
4. Replace the light globe that was removed, and then remove the other one.

Globes connected in series



Part B: Parallel circuits

5. Connect the two light globes, battery and wire leads as shown in the diagram.
6. Remove one light globe from its holder.
7. Replace the light globe that was removed, and then remove the other one.

Results

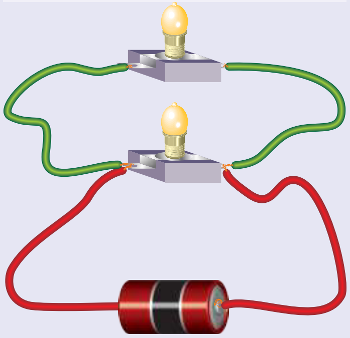
Part A: Series circuits

1. Draw a circuit diagram to represent the circuit that you have connected.
2. How does the brightness of the two light globes compare with the brightness of a single light globe connected to the same battery?
3. What effect does the removal of one light globe have on the other light globe when the battery is connected?
4. Does it matter which light globe is removed?

Part B: Parallel circuits

5. Draw a circuit diagram to represent the circuit that you have connected.
6. How does the brightness of the two light globes compare with the brightness of a single light globe connected to the same battery?
7. What effect does the removal of one light globe have on the other light globe?
8. Does it matter which light globe is removed?
9. Outline whether the removal of one light globe has any effect on the other light globe.
10. What would be the effect on the other light globes if a third light globe was added in parallel? Design a circuit to test your prediction.

Globes connected in parallel



Discussion

Part A: Series circuits

1. What would be the effect on the other light globes if a third light globe was added in series? Test your prediction.
2. Compare the current flowing through the circuit when one light globe is removed to the current flowing through the circuit when both light globes are connected.
3. Light globes in schools are sometimes connected in series. Describe a test you could do to detect whether the light globes in your classroom are connected in series or not.

Part B: Parallel circuits

4. Compare the current flowing in this parallel circuit when one light globe is removed compared to the current flowing when both light globes are connected.
5. Decorative lights connected in parallel are often more expensive than decorative lights connected in series. Provide a reason for this difference in cost.

Conclusion

What can you conclude about the flow of current in series and parallel circuits?

EXTENSION: Identical light globes

In series and parallel circuits, identical light globes will always have the same brightness. If additional identical light globes are added to a series circuit, the light globes will become dimmer. If identical light globes are added to a parallel circuit, the light globes will not change brightness.

What happens if the light globes in a series or parallel circuit are not identical?

ACTIVITY: PhET simulation

Access the **PhET simulation: Circuit construction kit: DC** interactivities in the Resources panel.

10.3 Activities

learnon

10.3 Quick quiz on	10.3 Exercise

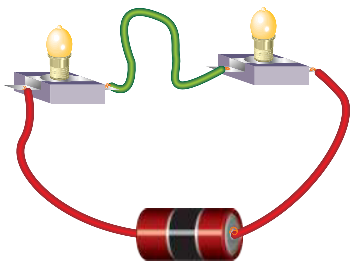
LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 4, 8, 9	3, 5, 6, 7, 11, 15, 16	10, 12, 13, 14, 17, 18, 19

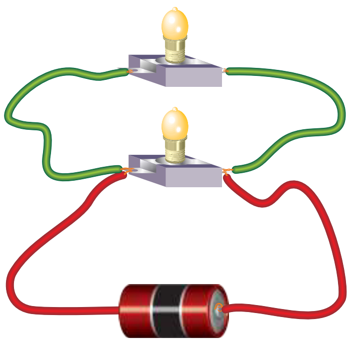
Remember and understand

1. Match the components to the three essential features of all electric circuits.

Component	Essential features
a. Resistor	A. Power supply
b. Wires	B. Load
c. Battery	C. Conducting path

2. MC Which device measures potential difference?
   A. A motor
   B. A thermistor
   C. An ammeter
   D. A voltmeter
3. **Describe** how an ammeter must be connected in an electric circuit and state which terminal of the ammeter must be connected closest to the positive terminal of a battery.
4. Complete the following sentences by choosing the correct word from the pair of words in italics.
   A. When light globes are connected in *series/parallel*, the same electric current flows through each light globe. The light globes share the voltage of the power supply.
   B. When light globes are connected in *series/parallel*, the electric current splits to be shared by the light globes. Each globe uses the same voltage.
5. Draw a circuit diagram of each of the circuits shown.





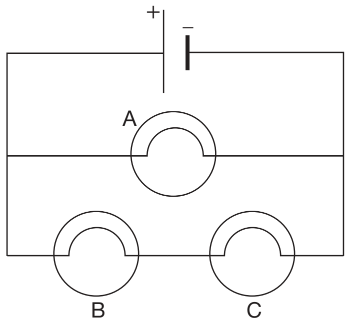
6. **Explain**, in words and without the use of a diagram, the difference between a circuit with two light globes in series and a circuit with two light globes in parallel.
7. **Describe** how an ammeter must be connected in an electric circuit and state which terminal of the ammeter must be connected closest to the positive terminal of a battery.

Apply and analyse

8. Match the device to its purpose.

Device	Purpose
a. Switch	A. Transducer turning electrical energy into light and heat
b. Light globe	B. A means of measuring a current at a point in a circuit
c. Ammeter	C. A way of turning the current in a circuit on or off

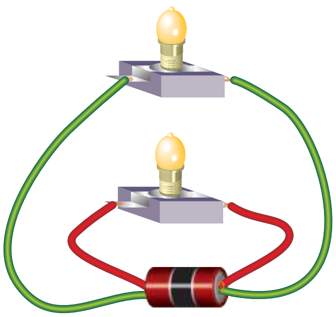
9. In a small shop, the six light globes are in series. One switch is used to switch all the lights on or off at once. Draw a circuit diagram of this circuit.
10. **Examine** the circuit diagram shown and answer the following questions.
    a. If the filament of light globe A breaks, which light globes, if any, remain working?
    b. If the filament of light globe B breaks, **identify** which light globes, if any, remain working.
    c. If the filament of light globe C breaks, **identify** which light globes, if any, remain working.



11. In a house, six light globes are in parallel. However, the lights are in separate rooms. This means that a separate switch is needed for each globe. Draw a circuit diagram of this circuit.
12. SI **Describe** two causes of systematic errors when using a voltmeter or ammeter.
13. When using an ammeter, you are advised to use the positive terminal with the highest value scale first. If you can choose between a 50-mA scale and a 500-mA scale, which one should you connect first? **Explain** your answer.
14. SI Can random errors be eliminated by using digital measuring instruments? **Explain** your answer.

Evaluate and create

15. **Describe** how a torch works. Ensure that the words 'current energy' and 'circuit' appear in your description.
16. Draw circuit diagrams for the following circuits. Make sure you include a switch so that you can turn the lights on and off.
    a. a cell connected to two light globes connected in series
    b. a cell connected to two light globes connected but not in series.
17. Draw a circuit diagram of a two-battery torch with a closed switch.
18. **Examine** the circuit shown.



    a. If the two light globes are identical, how much of the current flowing through the battery will flow through each light globe?
    b. In what way is this circuit similar to the one in part B of investigation 10.4?
    c. In what way is this circuit different from the one in part B of investigation 10.4?
19. SI Design a circuit with two switches and an electric bell, so that the bell rings only when both switches are closed. Draw a picture and circuit diagram of your circuit. Invent your own symbol for the bell. If a bell is not available, use a light globe instead.

Answers and sample responses are available in your digital formats.

LESSON 10.4 Controlling electrical devices

LEARNING INTENTION

In this lesson you will describe how sensors, and other devices, are used to control electrical devices, including robots.

10.4.1 Variable resistors

When you turn down the volume of a television, you are changing the voltage drop across and current flowing through parts of the electric circuits inside. The volume dial or sliding knob is part of a **variable resistor**.

Many resistors have the same resistance in all situations and their resistance cannot be changed. However, the resistance of a variable resistor can be changed.

Three different types of carbon resistors are shown in figure 10.15, at the left of the photo. The two can-shaped resistors at the right are a type of variable resistor used in volume dials.

FIGURE 10.14 There are several symbols that can be used to represent variable resistors.

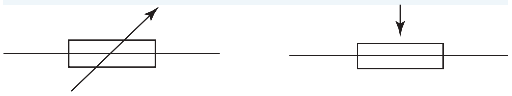
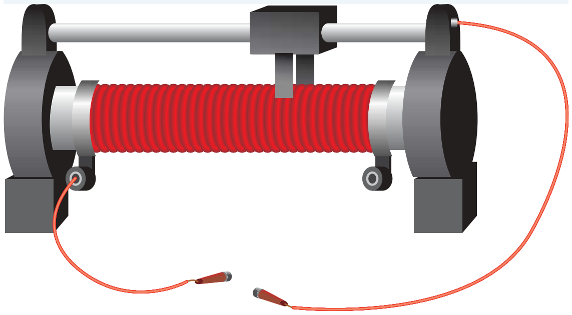


FIGURE 10.15 A range of carbon resistors

FIGURE 10.16 This variable resistor consists of coils of wire touched by a slider. The slider is connected to the coil, and controls the number of coils through which the current flows and, therefore, the resistance.



EXTENSION: Coiled variable resistor

Look carefully at the image of the coiled variable resistor with slider shown in figure 10.16. How do you think you would increase its resistance? Where could a variable resistor like this one be used? How would this variable resistor need to be modified if it were to be controlled by a dial instead of a slider?

A variable resistor can be used in a circuit to control the voltage across a light globe and the electric current flowing through the light globe. As the resistance of the variable resistor increases, this causes a decrease in the amount of current flowing through the light globe, which will dim the globe.

The amount of available electrical energy transformed in the light globe will also decrease. As the resistance of the variable resistor increases, more electrical potential energy is lost in heating the resistor and the surrounding air. Consequently, the globe glows less brightly because not only does less electric charge pass through it every second, but each electric charge has less energy to heat the globe's filament.

INVESTIGATION 10.5

Making the change

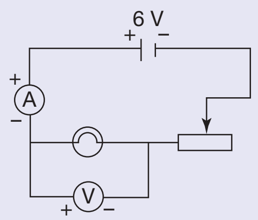
Aim

To investigate the effect of a variable resistor on a light globe connected with it in series

Materials

- power supply (set to 6 V)
- 6-V light globe and holder
- variable resistor
- 6 connecting leads with alligator clips or banana plugs
- ammeter and voltmeter

Method



1. Construct a table in which you can record five sets of measurements of voltage across the light globe and electric current flowing through the light globe.
   - Set up the circuit shown in the diagram. The variable resistor is connected in series with the light globe. Move the sliding part of the variable resistor so that the voltage drop across the light globe is at a maximum.
2. Record the voltage and current shown on the meters.
   - Move the sliding part of the variable resistor to four different positions, gradually reducing the voltage across the light globe.
3. Record the voltage and current in your table for each position.
   - Adjust the variable resistance so that the light globe is at its brightest.
   - Move the voltmeter so that it measures the voltage across the variable resistor.
4. Take note of the voltage.
   - Adjust the resistance to make the light globe dimmer and dimmer.
5. Take note of how the voltage across the variable resistor changes.

Discussion

6. What would you expect the resistance of the variable resistor to be when the voltage drop across the light globe is at a maximum?
7. What happens to the electric current flowing through the light globe as the resistance of the variable resistor increases?
8. What happens to (a) the voltage across the light globe and (b) the brightness of the light globe as the resistance of the variable resistor increases?
9. When the light globe is at its brightest, what is the voltage across the variable resistor?
10. How does the voltage across the variable resistor change when the globe is made dimmer?
11. What would you expect the sum of the voltage across the light globe and the voltage across the variable resistor to be?

Conclusion

Write a paragraph explaining how a variable resistor affects the brightness of the light globe. Include the words, current, voltage, resistance, energy and circuit in your paragraph.

10.4.2 Resistors in sensors

In **sensors**, such as those used in lights that automatically turn on when it gets dark, **light-dependent resistors (LDRs)** are used to switch lights off and on. The resistance of LDRs changes with the amount of light falling on them, changing the voltage to turn lights off or on. Most LDRs are made of substances that have less resistance when the light intensity increases.

Thermistors, such as those used in the heat sensors in air conditioners, refrigerators, car engine cooling systems and fire alarms have a resistance that changes as the temperature increases or decreases. As the thermistor's resistance changes, the voltage drop across the thermistor also changes. This change in voltage drop can be used to turn a heating or cooling unit on and off when needed.

Infrared sensors are used in a number of devices and recent-model cars to measure distances to nearby objects or to detect movement. An infrared beam is directed away from the device and the sensor detects whether the signal is reflected from the object. A computer in the device calculates the distance and sends a warning signal or even takes action to avoid the object. The sensor will have a resistance that changes when infrared light shines onto the sensor. When the resistance changes, the voltage drop across the sensor will also change. The change in voltage drop signals to the rest of the electric circuit that an object has been detected.

Other common sensors, including carbon dioxide sensors, colour sensors, humidity sensors and pressure sensors, operate in a similar way when they are included in electrical circuits. The resistance of the sensor changes when the environment changes. This leads to a change in the voltage drop across the sensor that can be used to turn an appliance on or off.

10.4.3 Controlling electrical devices

When the sensors discussed above are connected in a circuit with electronics programmed to respond in particular ways, such as in a robot, complex responses can occur when the light level, temperature, carbon dioxide level, among other things, change. This is how robots appear to interact with people and their environment. If an infrared sensor in a robot detects movement coming from the robot's right-hand side, the robot can then respond by turning to face the person. If a colour sensor in a robot detects different types of light energy reflecting off objects, the robot can then respond by sorting the objects based on their colour. It would appear as if the robot is thinking for itself, but really it is using sensors to gather information about its environment and then responding in a predictable way.

DISCUSSION

What aspects of the environment in your home or school would you like to control? What type of sensor would you need to detect these changes? How would the rest of the electric circuit need to behave in response to your sensor?

SCIENCE AS A HUMAN ENDEAVOUR: Sensors and control devices

Sensors and control devices have revolutionised modern technology by enabling automated systems, including robots, to respond to their environments. These technologies integrate knowledge from physics, engineering, computer science and other disciplines to create innovative solutions for diverse applications.

By combining expertise from multiple fields, scientists and engineers have developed highly efficient systems that improve productivity, safety and convenience. For example, robots equipped with sensors can perform repetitive or hazardous tasks, reducing risks for humans. Leading institutions, such as the Massachusetts Institute of Technology (MIT) and its Computer Science and Artificial Intelligence Laboratory (CSAIL), are at the forefront of sensor and robotics research. Companies such as Boston Dynamics have created robots capable of navigating complex environments, while NASA's Jet Propulsion Laboratory (JPL) uses sensor-equipped robots for planetary exploration.

In Australia, institutions such as CSIRO (Commonwealth Scientific and Industrial Research Organisation) are leading efforts in robotics and sensor technology. CSIRO has developed autonomous robotic systems for industries such as mining and agriculture, enabling efficient and safer operations. Their robotics team is also involved in advancing underwater drones and space exploration technologies, integrating sensors to navigate and perform complex tasks in challenging environments.

These advancements are not only technological marvels but also have profound implications for industries, healthcare and environmental monitoring. For instance, robotic systems with precise sensors are employed in disaster response scenarios, manufacturing automation and even performing surgeries, showcasing the far-reaching impact of these technologies.

Key features

- Integration of sensors and control devices for automation
- Multidisciplinary collaboration for technological advancement
- Real-world applications in manufacturing, healthcare and exploration

1. How do sensors convert physical changes into electrical signals?
2. What roles do control devices play in automated systems?
3. Give examples of how robots equipped with sensors and control devices are used in everyday life.
4. How do different disciplines contribute to the development of robots and automated systems?
5. **Discuss** the societal and ethical implications of increased automation in industries.
6. What are some notable contributions of Australian institutions such as CSIRO to robotics and sensor technology?

Multidisciplinary endeavours to advance scientific knowledge make use of people's different perspectives and worldviews (VC2S8H02)

10.4 Activities

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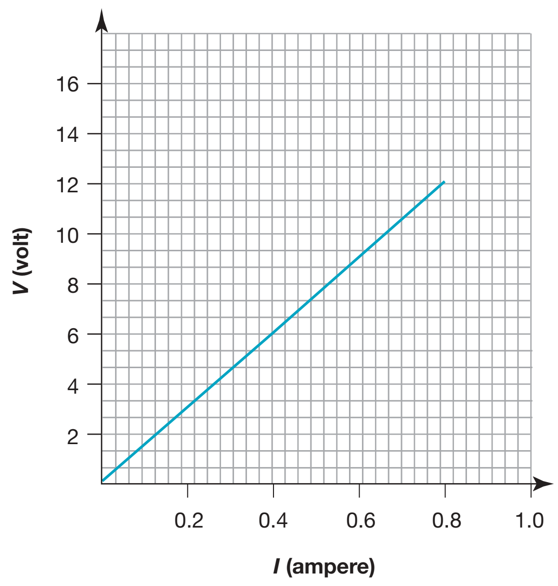
10.4 Quick quiz on	10.4 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
2, 4, 5	1, 3, 6, 7	8, 9, 10

Remember and understand

1. Use the graph, showing the current through and voltage drop across a non-variable resistor, to answer the following questions:

Graph of voltage drop (*V*) versus electric current (*I*) for an ohmic conductor



a. **Identify** what the current is when the voltage drop across the resistor is 10 V.
b. **Identify** what the voltage drop is across the resistor when the current flowing through the resistor is 0.4 A.
c. Is this resistor made from metal or plastic? **Justify** your response.

2. **Define** a variable resistor.
3. **List** three appliances that use temperature sensors.

Apply and analyse

4. **Compare** a variable resistor to a non-variable resistor.
5. **Explain** what happens to the current through a variable resistor when the resistance decreases.
6. **Describe** how an LDR can be used to turn street lights on and off.
7. **Discuss** some of the problems you might have to overcome when baking a cake if thermistors did not exist.

Evaluate and create

8. **Explain** how an air conditioner keeps the air in a room at a relatively constant, cool temperature.
9. You want to build a robot to help you tidy your bedroom. What sensors should you include in your robot design? **Explain** your choices.
10. You have been given a thermistor to use when constructing a heater for your classroom, but you do not know whether the resistance increases or decreases as the classroom temperature gets hotter. Write a method for an experiment to solve your problem.

Answers and sample responses are available in your digital formats.

LESSON 10.5 Household electricity

LEARNING INTENTION

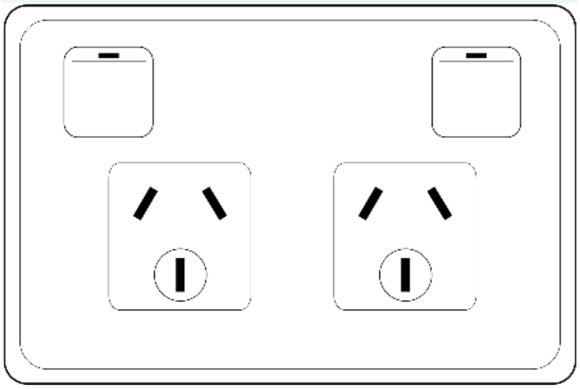
In this lesson you will examine electrical power points, household circuits, LEDs and electrical safety.

10.5.1 Electrical power points

The electric current supplied by a cell or battery is called **direct current** (DC). It flows in one direction only. The electric current provided to your home by power stations is called **alternating current** (AC). It changes direction about fifty times every second. In household lights and appliances, electrical potential energy is transformed into other forms of energy as electrons move backwards and forwards.

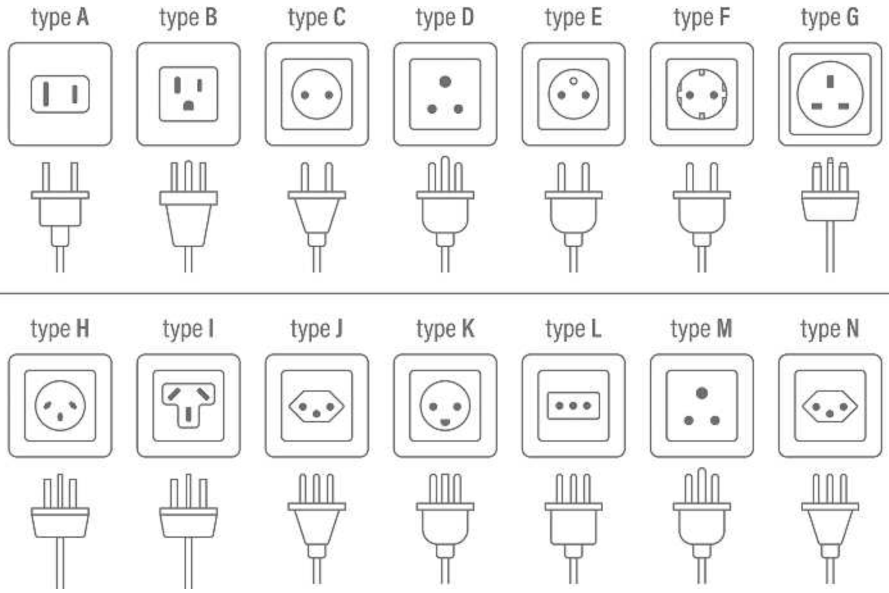
Alternating current, rather than direct current, is supplied by power stations because it is easier and cheaper to generate. It is also easier and cheaper to distribute widely over large distances. In Australia, electricity is supplied to homes at a voltage of 230 V.

FIGURE 10.17 An Australian power point with room for two power cords on two different circuits. Each circuit contains a switch to complete or open the circuit. The two angled sockets carry current into and out of an appliance, completing an electric circuit. The third (vertical) socket is a safety feature.



The electric cable that carries alternating current to your home holds two wires, one bringing the energy into your house and one taking energy away. Both wires are needed to make sure your house is part of an electric circuit. When the **main switch** in your home's meter box is open, current does not flow through the wires in the cable. The circuit is not complete. When the main switch in your meter box is closed, electric current is able to flow through these wires. However, it flows only when other switches inside your house (such as light and appliance switches) are closed.

FIGURE 10.18 Power points in other countries have differently shaped and arranged sockets. Every country has at least two sockets allowing current to flow into and out of appliances, creating a full electric circuit.



10.5.2 Household circuits

Every house contains a large number of electric circuits. These paths start and end at a meter box. You can count the number of paths electricity can take around your house by looking at the number of different switches inside your meter box. There will also be a main switch in the meter box that can turn off all the electricity to your entire house.

Appliances are normally connected in parallel with other appliances on the same path. This allows all appliances to receive 230 V of electrical potential energy and to receive the exact amount of current they need to operate normally and efficiently. Connecting appliances in parallel also allows each appliance to be turned on and off individually. Imagine if your fridge turned off every time you turned the kitchen lights off! Parallel paths also allow each appliance to continue operating if another one breaks down.

FIGURE 10.19 An example of a household meter box. The switches for different electrical paths inside the house are arranged horizontally. Below each switch is a label describing which appliances are connected to each specific path.

ACTIVITY: Meter box

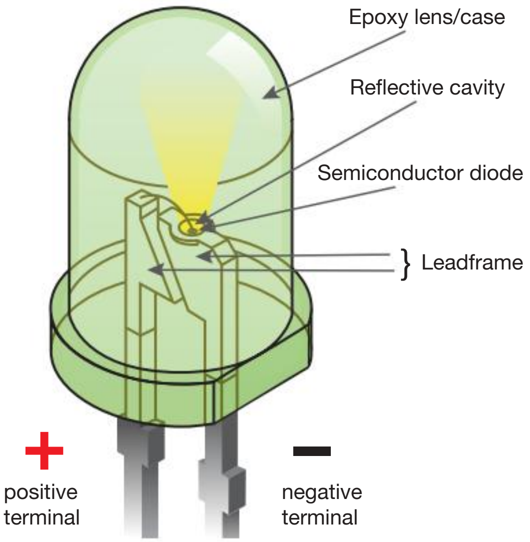
1. Find the meter box for your home.
2. Count the number of different paths electricity can take around your home.
3. Using the labels, record the types of appliance on each different path.
4. If a path has multiple appliances, try and work out if the appliances are connected in series or in parallel.

10.5.3 LED lights

The light globes previously used in Australian homes are called incandescent light globes. In incandescent light globes, electric current passes through a thin filament, generally made of tungsten metal, causing it to glow white hot. These light globes are inefficient as only 10 per cent of the supplied electrical potential energy is transformed into light energy; the rest becomes non-useful thermal energy.

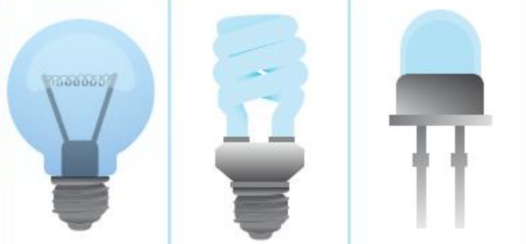
The sale of incandescent light globes was phased out from 2010 and energy efficient alternatives became available. These alternatives include compact fluorescent lamps (CFLs) and light emitting diodes (LEDs), which convert closer to 70 per cent of electrical energy to light.

FIGURE 10.20 The components of an LED



LEDs contain an electronic component called a semiconductor diode, similar to the miniature electrical components contained in an integrated circuit in a mobile phone or computer. When electricity flows through an LED, the electrical energy is converted to light energy very efficiently with minimal heat produced. One individual LED does not produce as much light as one CFL or one incandescent light globe, so many small LEDs are often used together for lighting purposes. You can see these individual LEDs as dots of light on speed limit signs around schools or the brake lights of many cars.

FIGURE 10.21 CFLs and LEDs are energy efficient alternatives for lighting.



	Incandescent light bulbs	Compact fluorescent lamps (CFLs)	Light emitting diodes LEDs
Electrical power use equivalent to 60 W incandescent light bulb	60 W	13–15 W	6–8 W
Electrical energy use per year based on 20 lights operating 8 hours per day	3506 kWh/yr	760 kWh/yr	350 kWh/yr
Approximate annual operating cost at 21 cents per kWh	$736	$160	$74

DISCUSSION

Why is it important to use energy efficient sources of light? Why do you think some venues use fluorescent lighting, yet we are encouraged to use LED lights at home?

10.5.4 Electricity safety

The appliances and lights in your home are all connected in parallel. There are normally separate parallel circuits for lights and power points. In addition, there may be separate circuits for each large appliance such as a fridge, dishwasher, washing machine or clothes dryer. If too many appliances or lights are turned on at once, the total current could become too large to be safe. In this situation, a **fuse** or **circuit breaker** can open the main circuit and stop the flow of current. A set of fuses or circuit breakers can be found in your meter box at home. A fuse is a short piece of wire that melts if the current gets too high. A circuit breaker is a special switch that opens automatically if the electric current gets too high. Almost all Australian houses now have safety switches; however, if you live in a very old building and the wiring has not been updated, you might still have fuses.

Safety switches

Fuses and circuit breakers open circuits before they overheat. But they work too slowly to stop people from getting an electric shock if there is a dangerously high current. Safety switches (also known as residual current devices) can turn off the power much more quickly — in less than one-thirteenth of a heartbeat — thus reducing the risk of death due to electric shock in the home.

FIGURE 10.22 The switch on the left is a safety switch. The other switches are circuit breakers.

Take care at home!

The 230-V AC household power supply can kill. If you tamper with working appliances or electrical wiring, it is possible that electric current will flow through your body. Electrocution — death from electric shock — can be caused by electric currents as low as 0.05 amperes flowing through your body.

One of the biggest causes of electrocution in the home is the use of damaged cords and plugs. If appliance cords and plugs are frayed or damaged, exposing the smaller plastic covered wires inside, the appliance should be replaced or taken to a qualified repairer.

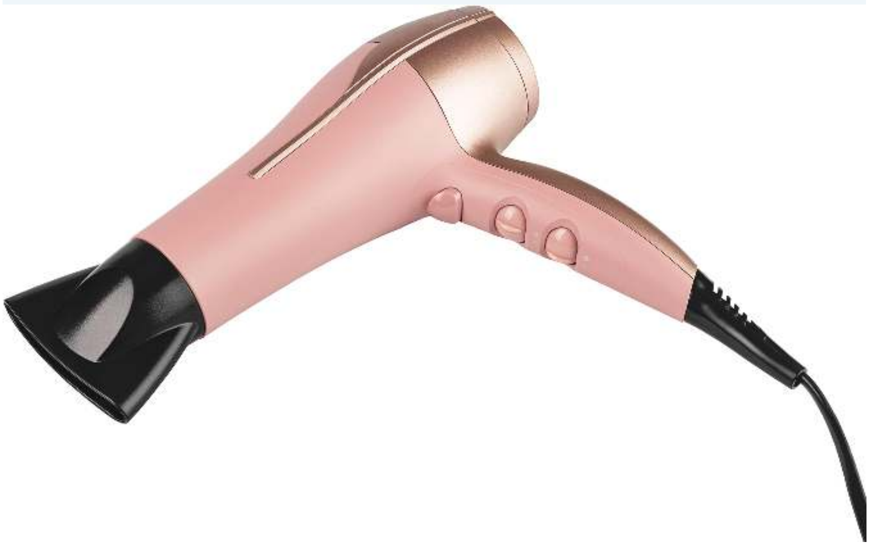
The bathroom can be a very dangerous place in which to use electrical appliances. Tap water contains charged particles (ions) due to substances dissolved in it. It is therefore a good conductor of electric current. Appliances such as hair dryers, heaters and electric shavers should never be used when there is water in the basin or bath, or when there is water on the floor. If a working appliance was to fall into some water, you could be electrocuted if you came in contact with the appliance, either by accidentally touching it or by trying to pick it up.

Why are there three?

Australian power points have three sockets as an added safety feature. When you plug in an electrical device and switch on the power, alternating current flows between the top two sockets through the appliance. The third socket, called the **earth socket**, is connected to a metal pipe in the ground. The earth socket is a safety device to help prevent electrocution from faulty appliances.

If an electrical device has an uninsulated metal casing, its plug has three pins. The bottom pin is connected by a wire to the metal casing. This pin fits into the earth socket. If there is a fault in the appliance, and the metal casing becomes 'live', electric current flows to the ground, rather than through the body of a person touching the metal. Appliances with two-pin plugs are 'double insulated' to make them safe. Any metal on the outside of these appliances is insulated with plastic. This prevents electric current from flowing from the metal to the wiring inside.

FIGURE 10.23 Hand-held electrical appliances such as this hairdryer are often double insulated.



ACTIVITY: Electrical safety feature

Research an electrical safety feature or device common in homes and/or schools. Find out:

- how the device or feature works
- where it should be located within an electric circuit
- the conditions needed to activate the device or feature
- the time it takes for the device or feature to function
- when the device or feature was first used and if it is still in use now.

Combine your information into a poster on electrical safety to be displayed in your classroom.

10.5 Activities

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10.5 Quick quiz	10.5 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
2, 4, 5	1, 3, 6, 7	8, 9

Remember and understand

1. **Suggest** what should be done when appliance cords or plugs become frayed or the plastic coating cracks or breaks.
2. **Explain** why you need to be extra careful when using electric appliances in the bathroom.
3. **State** a reason for using LED lights instead of incandescent light globes.
4. a. If there are six switches in your meter box (not including the main switch), how many different paths can electricity take around your house?
   b. What does the main switch in the meter box do?

Apply and analyse

5. **Compare** fuses and safety switches.
6. **Explain** the role of a circuit breaker in a house.
7. **Describe** the impact on an electricity bill of replacing incandescent or fluorescent light globes with LED lights.

Evaluate and create

8. Create a list of points that you need to include when thinking about designing a poster explaining how a safety switch works.
9. You have a fridge, a toaster and a kitchen light connected in *parallel* in your home.
   a. If the fridge needs 230 V to keep your food cold, how much voltage does the toaster and kitchen light receive when they are all connected in parallel? **Explain** your answer using the information provided.
   b. One day, the toaster stops working. Will the fridge and kitchen light still work? **Explain** why this happens based on the way the appliances are connected.
   c. Imagine the appliances were connected in *series* instead of parallel. What might happen if the kitchen light was turned off? Would the fridge and toaster still work? **Explain** your answer.

Answers and sample responses are available in your digital formats.

LESSON 10.6 Review

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10.6 Success criteria

Tick the column to indicate that you have completed the lesson and how well you think you have understood it using the traffic light system.

(**Green:** I understand; **Yellow:** I can do it with help; **Red:** I do not understand)

Lesson	Success criteria	Green	Yellow	Red
10.2	I can define electrical charge, current, voltage and resistance and explain the role of each in an electrical circuit.			
	I understand how energy is transferred and transformed in an electrical circuit.			
10.3	I can identify series and parallel circuits and describe the differences between them.			
	I can predict the behaviour of current and voltage in both types of circuits.			
10.4	I can describe how sensors and other control devices are used to control electrical devices, including robots.			
10.5	I can examine electrical power points, household circuits, LEDs and electrical safety.			

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Post-test Topic 10 Post-test

eWorkbook Topic 10 eWorkbook

Digital document Key terms glossary

10.6 Activities

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10.6 Review questions

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 4, 6	3, 5, 7, 9, 14	8, 10, 11, 12, 13, 15

Remember and understand

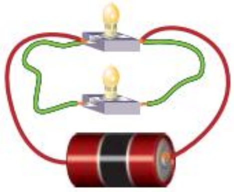
1. Match each term with its correct description.

Term	Description
Static electricity	A material that allows current or heat to flow through it
Electron	Positively charged particle in the nucleus of an atom
Proton	The build-up of charge on an object
Current	A material that does not allow current or heat to flow through it easily
Voltage	Particle in an atom with a negative charge
Conductor	A path that has no breaks in it
Closed circuit	The energy supplied to move electrons around a closed circuit
Insulator	The flow of electrons around a closed circuit

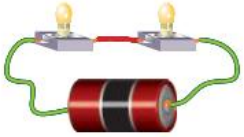
2. **Identify** each of the following circuits as a parallel circuit or series circuit.

a.

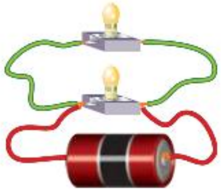
b.



c.



d.



3. MC In which one or more of the following arrangements will the globe light up?

A.

B.

C.

D.

4. MC What physical quantity describes a change in electrical potential energy?
   A. Voltage
   B. Current
   C. Resistance
   D. Power
5. Complete the table by writing down the missing quantity, unit or abbreviation.

Quantity	Unit	Abbreviation
Voltage	volt	
Electric current		A
	ohm	

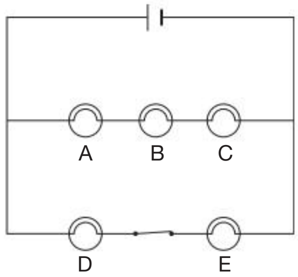
6. **Describe** how the resistance of each device can be changed:
   a. variable resistor
   b. LDR
   c. thermistor

Apply and analyse

7. Use symbols to draw a circuit containing a light globe in series with an ammeter, a battery and a switch.
8. Draw a circuit diagram that shows how a voltmeter and ammeter are used to measure the voltage across and current flowing through a single light globe connected to a 6-V power supply. Label the positive and negative terminals of the power supply and each meter with + and – symbols.
9. **State** the electric current shown on an ammeter if the positive lead is placed in the:
   a. 500-mA terminal
   b. 5-A terminal.
10. **Identify** how increasing the resistance of a variable resistor in series with a power supply and a lamp affect the:
    a. electric current in the lamp
    b. voltage drop across the variable resistor
    c. voltage drop across the lamp.

11. **Describe** how a water sensor could be used to help plants stay healthy.

Questions 12 and 13 refer to the circuit diagram shown. The light globes, labelled A to E, are identical to each other.



12. a. Which of the light globes are connected:
    i. in series with globe A
    ii. in parallel with globe A?
  b. If the voltage across globe C was measured to be 4 V, what is the voltage across:
    i. globe A
    ii. the terminals of the power supply
    iii. globe E?
  c. If the electric current flowing through globe B was measured to be 200 mA and the electric current flowing through globe D was measured to be 300 mA, what is the electric current flowing through:
    i. globe A
    ii. globe E
    iii. the power supply?
13. a. If the filament in globe B was to break, **name** the light globes that would remain glowing.
  b. If the switch in the circuit was opened, **name** the light globe that would stop glowing.
  c. **Suggest** how you could make all of the light globes stop glowing without opening the switch or turning off the power supply.
  d. The voltage across globe C is measured to be 4 V and the current flowing through it is 200 mA. **Identify** the electric current flowing through globe C, in amperes.

Evaluate and create

14. SI **Explain** in what way a constant resistor behaves differently from a thermistor.
15. A student set up four different circuits, labelled A, B, C and D. Using suitable instruments, the voltage and current in each circuit was measured. The results are shown in the following table.

Circuit	Voltage (V)	Current (A)
A	2.5	1.4
B	2.5	0.6
C	3.8	0.8
D	3.1	0.8

  a. **Compare** circuits A and B. Which circuit has the higher resistance? **Explain**.
  b. **Compare** circuits C and D. Which circuit has the higher resistance? **Explain**.

Answers and sample responses are available in your digital formats.

on To test your understanding and knowledge of this topic, go to your learnON title at www.jacplus.com.au and complete the **post-test**.

GLOSSARY

abrasive a property of a material or substance that easily scratches another
absorption the taking in of a substance; for example, from the intestine to the surrounding capillaries
abundant common, readily available in large amounts
abyssal plains relatively flat underwater deep-ocean floor, around 4000 metres depth
accumulation meters simple mechanical devices that count energy or resource usage on a numbered dial that has to be manually read during a site visit by a technician
accuracy how close a measurement is to the true value
active volcano a volcano that is erupting or has recently erupted
aim a statement outlining the purpose of an investigation
alchemist an olden-day 'chemist' who mixed chemicals and tried to change ordinary metals into gold; alchemists also tried to predict the future
alimentary canal see *gastrointestinal tract*
allergen an antigen that elicits an allergic response
allergy an abnormal immune response to a substance that is harmless for most people
alloy a mixture of a metal with a non-metal or another metal
alternating current electricity that changes direction many times per second; it is the type of electricity that comes from power outlets
alveoli tiny air sacs in the lungs at the ends of the narrowest tubes; oxygen moves from alveoli into the surrounding blood vessels, in exchange for carbon dioxide; singular = alveolus
ammeter device used to measure the amount of current in a circuit; ammeters are placed in series with other components in a circuit
ammonia a nitrogenous waste product of protein breakdown
amylases enzymes found in saliva that break starch down into sugar
analysis the use of tests and procedures to identify substances
anaphylaxis an acute and potentially lethal allergic reaction to an allergen to which a person has become hypersensitive
anticline a fold in a rock with the narrow point facing upwards
anus the end of the digestive system, through which faeces are passed as waste
aorta a large artery through which oxygenated blood is pumped at high pressure from the left ventricle of the heart to the body
appendix a small, tube-shaped organ attached to the large intestine; it does not have a clear role in digestion but may help the immune system when you are young
aqueous a solution with water as the solvent
arteries hollow tubes (vessels) with thick walls carrying blood pumped from the heart to other body parts
arterioles vessels that transport oxygenated blood from the arteries to the capillaries
asthma narrowing of the air pipes that join the mouth and nose to the lungs
atomic number the number of protons in the nucleus of an atom, which identifies the element to which the atom belongs
atoms very small particles that make up all things; atoms have the same properties as the objects they make up
axial tilt the difference between the axes of rotation of the Earth and Sun
basalt a dark, igneous rock with small crystals formed by fast cooling of hot lava; it sometimes has holes that once contained volcanic gases
batholith an intrusive rock mass that covers an area of over 100 square kilometres
beaker a container for mixing or heating substances
bile a substance produced by the liver that helps digest fats and oils
binocular microscope a microscope with two eyepieces through which the specimen is seen using both eyes
biodegradable describes a substance that breaks down or decomposes easily in the environment
biomass organic material from a plant or animal, often useful for its energy content or as a fertiliser
black smoker a geothermal vent on the sea floor that ejects superheated, mineral-rich water

blackouts occur when the electricity goes out completely in an area, often because of a problem with the power supply
bladder a sac that stores urine
blood cells living cells in the blood
blood pressure measures how strongly the blood is pumped through the body's main arteries
blood vessels the veins, arteries and capillaries through which the blood flows around the body
body systems groups of organs within organisms that carry out specific functions
body waves seismic waves that quickly travel through the interior of Earth
bolus a round, chewed-up ball of food made in the mouth that makes swallowing easier
bonded joined by a force that holds particles of matter, such as atoms, together
bones the pieces of hard tissue that make up the skeleton of a vertebrate
Bowman's capsule a cup-like structure at one end of a nephron within the kidney, surrounding the glomerulus; it serves as a filter to remove wastes and excess water
breathing the movement of muscles in the chest causing air to enter the lungs and the altered air in the lungs to leave; the air entering the lungs contains more oxygen and less carbon dioxide than the air leaving the lungs
brittle can easily break if hit; the opposite of malleable
bronchi the narrow tubes through which air passes from the trachea to the smaller bronchioles and alveoli in the respiratory system; singular = bronchus
bronchioles small, branching tubes in the lungs leading from the two larger bronchi to the alveoli
brownouts occur when the electricity supply is reduced, causing lights to dim or devices to work poorly, but not turn off completely
burning combining a substance with oxygen in a flame
burping the release of swallowed gas through the mouth
calibrate to check or adjust a measuring instrument to ensure accurate measurements
capillaries numerous tiny blood vessels that are only a single cell thick to allow exchange of materials to and from body cells; every cell of the body is supplied with blood through capillaries
carbon dioxide a colourless gas (CO_2) made up of one carbon and two oxygen atoms; it is essential for photosynthesis and is a waste product of cellular respiration; a potent greenhouse gas, principally emitted during the combustion of fossil fuels
carbon sequestration the process of removing carbon dioxide from the atmosphere and storing it in a stable form and location
carbon sink a material that absorbs and retains more carbon than was emitted in its production
carcinogens chemicals that cause cancer
cardiac muscle a special kind of muscle in the heart that never tires; it is involved in pumping blood through the heart
carnivore an animal that eats other animals
cast a fossil cavity that has been filled with minerals or other matter
cell the smallest unit of life; cells are the building blocks of living things and can be many different shapes and sizes
cell membrane the structure that encloses the contents of a cell and allows the movement of some materials in and out
cell theory the theory that states that all living things are made up of cells and that all cells come from pre-existing cells
cellular respiration a series of chemical reactions in which the chemical energy in molecules such as glucose is transferred into ATP molecules, which is a form of energy that the cells can use
cellulose a natural substance that keeps the cell walls of plants rigid
chemical change a change that results in at least one new substance being formed due to the breaking and forming of chemical bonds and rearrangement of atoms in a reaction
chemical digestion the chemical reactions that change food into simpler substances that are absorbed into the bloodstream for use in other parts of the body
chemical formula shows the ratio of the atoms of each element present in a molecule or compound
chemical properties properties that describe how a substance combines with other substances to form new chemicals, or how a substance breaks up into two or more different substances

chemical reaction a chemical change between two or more substances in which one or more new chemical substances are produced
chemical symbol the standard way that scientists write the names of the elements, using either a capital letter or a capital followed by a lowercase letter; for example, carbon is C and copper is Cu
chlorophyll the green-coloured chemical in plants, located in chloroplasts, that absorbs light energy so that it can be used in the process of photosynthesis
chloroplasts oval-shaped organelles that are involved in the process of photosynthesis, which results in the conversion of light energy into chemical energy
circuit breaker a safety switch that automatically turns off the electricity if there is a problem, such as too much current
circuit diagram diagram using symbols to show the parts of an electric circuit
circulatory system the heart, blood and blood vessels, which are responsible for circulating oxygen and nutrients to body cells, and carbon dioxide and other wastes away from them
coal a sedimentary rock formed from dead plants and animals that were buried before rotting completely, followed by compaction and some heating
collision refers to when two continents crumple together to form a mountain range
colloid a mixture in which a microscopically insoluble substance is dispersed and suspended throughout another substance
colon the part of the large intestine where food mass passes from the small intestine, and where water and other remaining essential nutrients are absorbed into the body
combustion the process of combining with oxygen, most commonly burning with a flame
components in circuits are the individual electrical devices that are connected in the circuit by conducting wires
compound a substance made up of two or more different types of atoms that are chemically bonded (covalent or ionic) together
compression a squeezing force
conducting path connected series of materials along which an electric current can flow
conduction energy transfer between two surfaces that are in direct contact, occurring due to collisions between high-energy and low-energy molecules
conglomerate a sedimentary rock containing large fragments of various sizes cemented together
continental drift the movement of Earth's continents relative to one another over geologic time
control an experimental set-up in which the independent variable is not applied; a control is used to ensure that the result is due to the variable and nothing else
controlled variables the conditions that must be kept the same throughout an experiment
convection movement of thermal energy within a liquid or gas; hotter fluids are less dense, causing the denser colder material to sink
convection currents the movement of particles in a liquid or gas resulting from a temperature or density difference
convergent boundary where two tectonic plates move towards each other
core the hot centre of Earth made of heavy iron and nickel
corrosion a chemical reaction between air, water or chemicals in the air or water with a metal, which causes the metal to wear away
cytoplasm the jelly-like material inside a cell; it contains many organelles, such as the nucleus and vacuoles
cytosol the fluid found inside cells
crust the hard, thin outer rock layer of Earth
crystal a geometrically shaped substance made up of atoms and molecules arranged in one of seven different shapes; the elements and the conditions present during the crystal's growth determine the arrangement of atoms and molecules and the shape of the crystals
cullet used glass
data information collected that can be used for studying or analysing
decomposers organisms that live in the soil which break down organic material
decomposition the breaking up of a substance into smaller parts
deep-ocean trenches narrow and deep troughs in the ocean floor, generally greater than 5000 metres depth

degasification removing all gas powered appliances, to be replaced by electrically powered equivalents
delta a landform created by the deposition of sediment at the end of a river as it enters a body of water
denatured describes the condition of proteins after they have been overheated
deoxygenated blood blood from which some oxygen has been removed
dependent variable a variable that is expected to change when the independent variable is changed; the dependent variable is observed or measured during the experiment
deposit a natural collection of minerals or rocks in the ground, like gold or coal, that can be mined
deposition the settling of transported sediments
diaphragm a flexible, dome-shaped muscular layer separating the chest and the abdomen; it is involved in breathing
diarrhoea excessive discharge of watery faeces
diastolic pressure the lower blood pressure reading during relaxation of the heart muscles
diffusion movement of molecules through the cell membrane
digestion the breakdown of food into a form that can be used by an animal; it includes both mechanical digestion and chemical digestion
digestive system a complex series of organs and glands that processes food to supply the body with the nutrients it needs to function effectively
direct current electricity that flows in one direction only, such as the power from a battery
dissolved refers to when a solid substance integrates into the liquid solvent
divergent boundary where two tectonic plates move apart
dormant volcano a volcano that has erupted in the last 10 000 years but is not currently erupting; such a volcano is considered likely to erupt again
ductile capable of being drawn into wires or threads; a property of most metals
ductility the ability of a material to be stretched or drawn into a wire or thin shape without breaking
durability the quality of lasting; not easily being worn out
earth socket a part of a power outlet that connects to the ground (Earth) to help prevent electric shocks
earthquake a sudden and violent shaking of the ground
ectothermic describes an animal whose body temperature is determined by its environment
efficiency in energy terms, the fraction of energy supplied to a device as useful energy
elastic describes a material that is able to return to its original size after being stretched
elasticity the property that allows a material to return to its original size after being stretched
electric charge physical property of matter that causes it to experience a force when near other electrically charged matter; electric charge can be positive or negative
electric circuit a path that electricity flows through; it usually includes wires, a power source (such as a battery) and something that uses the electricity (such as a light bulb)
electric current a measure of the number of electrons flowing through a circuit every second
electrical circuit consists of a power supply, a conducting path for charge to flow and one or more loads
electrical conductors materials through which electricity flows easily
electrical energy energy made by moving electric charges; it powers things such as lights, appliances and computers
electrical insulators materials which do not allow electricity to flow easily
electrocardiogram (ECG) a graph made using the tiny electrical impulses generated in the heart muscle, giving information about the health of the heart
electromagnetic radiation the radiant energy such as radio waves, infrared, visible light, x-rays and gamma rays released by magnetic or electric fields
electromagnetic spectrum the complete range of wavelengths of energy radiated as electric and magnetic fields
electron a tiny particle that moves around the nucleus of an atom; it has a negative electric charge
electron microscope an instrument used for viewing very small objects; an electron microscope is much more powerful than a light microscope and can magnify things up to a million times
elements pure substances made up of only one type of atom
emphysema a condition in which the air sacs in the lungs break open and join together, reducing the amount of oxygen taken in and carbon dioxide removed
emulsify to combine two liquids that do not normally mix easily

endocrine system the body system of glands that produce and secrete hormones into the bloodstream to regulate processes in various organs
endothermic describes an animal that can internally generate heat to maintain its body temperature
energy rating a measure of energy efficiency for appliances sold in Australia
Environmental impact statement (EIS) a report on the possible effects of a planned project on the environment
enzymes special chemicals that speed up reactions but are themselves not used up in the reaction
epicentre the surface point directly above the earthquake focus
epiglottis a leaf-like flap of cartilage behind the tongue that closes the air passage during swallowing
erosion the wearing away and removal of soil and rock by natural elements, such as wind, waves, rivers and ice, and by human activity
erythrocytes red blood cells
eukaryote any cell or organism with a membrane-bound nucleus (e.g. plants, animals, fungi and protists)
evaporates changes state from a liquid to a gas
excretion the removal of wastes from the body
excretory system the body system that removes waste substances from the body
exoskeleton a skeleton or shell that lies outside the body
extinct volcano a volcano that *has not* erupted in the last 10 000 years; they are considered dead and not to erupt again
extrusive describes igneous rock that forms when lava cools on Earth's surface
fair test a test that changes only one variable and controls all other variables when attempting to answer a scientific question
fault a break in the crust where one side moves relative to the other
filament coil of wire made from a metal that glows brightly when it gets hot
flammability an indicator of how easily a substance catches fire
flatulence the release of gas through the anus; this gas is produced by bacteria in the large intestine
flaccid refers to cells that are not firm due to loss of water
flint a fine-grained sedimentary rock that leaves a very sharp edge when broken
floodplain flat, open land beside a river where sediments are deposited during floods
focus the location underground of the fault movement causing an earthquake
folds refers to when rocks bend into anticlines or synclines
foliation consisting of an arrangement of certain mineral grains into distinct bands, which gives the rock a striped appearance
fossil any remains, impression or trace of a life form of a former geological age; evidence of life in the past
fossil fuel a substance, such as coal, oil or natural gas, that has formed from the remains of ancient organisms; coal, oil and natural gas are often used as fuels — that is, they are burnt in order to produce heat
friction the rubbing together of surfaces; all friction produces thermal energy (heat)
fuse a safety device in an electric circuit; if too much electricity flows, the fuse breaks the circuit to stop damage or fire
gabbro a dark-coloured, intrusive igneous rock with a similar mineral composition to basalt, but with larger crystals
gall bladder a small organ that stores and concentrates bile within the body
galvanising protecting a metal by covering it with a more reactive metal that will corrode first
gangue rock or mineral material of no commercial value in which valuable minerals or metals occur
gastrointestinal tract also called the digestive tract or the alimentary canal, it is a tubular passage that starts with the mouth and ends with the anus; it intakes and digests food (absorbing energy and nutrients) and expels waste
geosphere the materials that make up the interior of the planet, in contrast to the atmosphere, hydrosphere and biosphere
geothermal energy refers to using heat from Earth as an energy source
gingivitis a mild form of gum disease that causes red, swollen gums that may bleed when you brush your teeth
glaciers large bodies of ice that move down slopes and push boulders, rocks and gravel
Global Positioning System (GPS) a network of satellites that tracks location and movement

glomerulus a cluster of capillaries in the kidney that acts as a filter to remove wastes and excess water
glucose a six-carbon sugar (monosaccharide) that acts as a primary energy supply for many organisms
gneiss a coarse-grained metamorphic rock with light and dark bands formed mainly as a result of great pressure on granite
Gondwana the southern part of the broken-up supercontinent of Pangaea, which included the continents of Africa, South America, Antarctica and Australia; also known as Gondwanaland
granite a light-coloured, intrusive igneous rock with mineral crystals large enough to see
group in the periodic table of elements, a single vertical column of elements with a similar nature
guard cells cells on either side of a stoma that work together to control the opening and closing of the stoma
haemodialysis the process of passing blood through a machine to remove wastes
haemoglobin the red pigment in red blood cells that carries oxygen
hardness a measure of how difficult it is to scratch the surface of a solid material; hardness can be ranked using Mohs scale
hazardous substances chemicals that can cause harm
heart a muscular organ that pumps deoxygenated blood to the lungs to be oxygenated and then pumps the oxygenated blood to the body
heartbeat a contraction of the heart muscle occurring about 60–100 times per minute
heartburn a burning sensation caused by stomach acid rising into the oesophagus
herbivore an animal that eats only plants
heterogeneous has a non-uniform composition throughout
homogeneous has a uniform composition throughout
horst a highland between two normal faults
hotspot a volcanic region directly above an area of extremely hot mantle
hydrogen the element with the smallest atom and the most common element in living things; by itself, it is a colourless gas and combines with other elements to form a large number of substances, including water
hypothesis a suggested, testable explanation for observations or experimental results; it acts as a prediction for the investigation
igneous rocks rocks formed when hot, molten rock cools and hardens (solidifies)
independent variable the variable that the scientist chooses to change to observe its effect on another variable
inert not reactive
infrared sensors devices that detect heat or movement by sensing infrared light, which is a type of invisible heat energy
inner core the solid inner-most layer of the core under extreme pressure conditions, with an approximate 1200 km radius
intrusive describes igneous rock that forms when magma cools below Earth's surface
investigations activities aimed at finding information
joule (J) the SI unit of work or energy; one joule is equal to the amount of work done when a force of one newton moves a body through a distance of one metre in the direction of that force
kidneys body organs that filter the blood, removing urea and other wastes
kilowatt-hour (kWh) a large unit of energy appropriate for use on power bills
kinetic energy energy due to the motion of an object
large intestine the second last part of the digestive system, where water is absorbed from the waste before it is transported out of the body
Laurasia the northern part of the broken-up supercontinent of Pangaea, which included the continents of North America, Europe and Asia
lava an extremely hot liquid or semi-liquid rock from the mantle that reaches and flows or erupts on Earth's surface
left atrium the upper-left section of the heart where oxygenated blood from the lungs enters the heart
left ventricle the lower-left section of the heart, which pumps oxygenated blood to all parts of the body
leucocytes white blood cells
light dependent resistors (LDRs) a type of resistor that changes how much electricity it lets through depending on how much light hits it; more light equals less resistance

light microscope an instrument used for viewing very small objects; a light microscope can magnify things up to 1500 times

lignin a hard substance in the walls of dead xylem cells that make up the tubes carrying water up plant stems; lignin forms up to 30 per cent of the wood of trees

limestone a sedimentary rock formed from the remains of sea organisms; it consists mainly of calcium carbonate (calcite)

lipases enzymes that break fats and oils down into fatty acids and glycerol

lipids a class of nutrients that include fats and oils

liquefaction a phenomenon in which soil loses its strength and stiffness due to strong ground shaking

lithify to transform sediment into rock

lithosphere the outermost layer of Earth; includes the crust and uppermost part of the mantle

liver the largest gland in the body; it secretes bile for digestion of fats, builds proteins from amino acids, breaks down many substances harmful to the body and has many other essential functions

load shedding when electricity is turned off in some areas on purpose to stop the whole power system from failing

Love waves surface seismic waves that have a side-to-side motion

'lub dub' the sound made by the heart valves as they close

lungs the organ for breathing air; gas exchange occurs in the lungs

lustre the high shine and sheen of a substance caused by the way it reflects light

magma a very hot of molten rock and gases, just below Earth's surface, that forms from melting of the mantle and occasionally the crust

main switch a switch that turns off all the electricity in a building; it is used for safety or during repairs

malleability the ability of a material to be changed into a new shape without breaking; for example, to be pressed or hammered into thin sheets

malleable able to be beaten, bent or flattened into shape

mantle the solid but soft middle rock layer of Earth

marble a metamorphic rock formed as a result of great heat or pressure on limestone

mass extinction a widespread and rapid decrease in the biodiversity and abundance of life

magnification the number of times the image of an object has been enlarged using a lens or lens system; for example, a magnification of two means the object has been enlarged to twice its actual size

measuring cylinder a narrow container with marked lines indicating volume; used to measure volumes of liquids more precisely than a beaker or flask

mechanical digestion digestion that uses physical factors such as chewing with the teeth

metabolism the chemical reactions occurring within an organism that enable the organism to use energy and grow and repair cells

metal extraction the process of getting pure metal out of rocks or minerals, usually by heating or using chemicals

metalloids elements that have the appearance of metals but not all the other properties of metals

metals elements that conduct heat and electricity; shiny solids that can be made into thin wires and sheets that bend easily; mercury is the only liquid metal at room temperature

metamorphic rocks rocks formed from the change (alteration) of pre-existing rocks in response to increasing temperature and/or pressure conditions

metamorphism the process that changes rocks by extreme pressure or heat (or both)

micrometre one millionth of a metre

microscope an instrument used for viewing small objects

mineral a naturally occurring, inorganic and solid substance with a defined chemical formula and an ordered arrangement of atoms

mineral extraction the process of digging up minerals from the Earth so they can be used to make things such as metal, glass or electronics

mining the process of removing natural resources from Earth

mitochondria small, rod-shaped organelles that are involved in the process of cellular respiration, which results in the conversion of energy into a form that the cells can use

mixture a combination of substances in which each keeps its own properties (i.e. not chemically bonded)
molecule two or more atoms joined (bonded) covalently together
monocular microscope a microscope with a single eyepiece through which the specimen is seen using only one eye
mould a cavity in a rock that shows the shape of the hard parts of an organism
mountain range a group of high-ground features, commonly the result of tectonic collision
mouth the opening of the gastrointestinal tract through which food is taken into the body
mudstone a fine-grained sedimentary rock made of mud (clay and silt)
multicellular organisms living things comprised of specialised cells that perform specific functions
multicellular made up of many cells
muscles tissue consisting of cells that can shorten
musculoskeletal system consists of the skeletal system (bones and joints) and the skeletal muscle system (voluntary or striated muscle); working together, these two systems protect the internal organs, maintain posture, produce blood cells, store minerals and enable the body to move
nanometre one billionth of a metre
nanotechnology a science and technology that focuses on manipulating the structure of matter at an atomic and molecular level
native elements elements found uncombined in Earth’s crust
natural fibres fibres that form naturally — that is, they have not been made by humans; they include wool and silk from animals, and cotton from plants
nephrons the filtration and excretory units of the kidney
nervous system consists of neurons, nerves and the brain, which are responsible for detecting and responding to both internal and external stimuli
neutron a tiny particle in the nucleus of an atom; it has no electric charge (it is neutral)
Newton’s cradle a decorative device consisting of suspended metal balls that that can be made to swing backwards and forwards in a particular way
nitrogenous wastes waste products from protein breakdown, including ammonia, urea and uric acid
noble gases elements in the last column of the periodic table; they are extremely inert gases
non-metals elements that do not conduct electricity or heat; they melt and turn into gases easily, and are brittle and often coloured
non-renewable finite resources that are not replaced on a timescale of human lifetimes
normal fault a break where the rock above the fault moves ‘down’ due to tension
nucleus the centre of an atom, made up of protons and neutrons; it holds most of the atom’s mass
nutrients substances that provide the energy and chemicals that living things need to stay alive, grow and reproduce
nylon a synthetic fibre; the monomers are joined together by the elimination of water molecules at the joins
observations information obtained by the use of our senses or measuring instruments
obsidian a black, glassy rock that breaks into pieces with smooth shell-like surfaces
ocean ridges submarine mountains that tower 2000 metres above the abyssal plains
oesophagus part of the digestive system, composed of a tube connecting the mouth with the stomach
old-growth forests forests that have grown for a very long time without being cleared or disturbed; they have tall trees, rich wildlife and are important for the environment
open-cut mining mining that removes soil and rocks on the surface of the land
ophiolites pieces of oceanic crust observed on continental crust (land)
ore mineral a mineral from which a valuable metal can be removed for profit
organelle any specialised structure in a cell that performs a specific function
organisms living things, such as animals and plants, that grow, change and need food, water and air to survive
organs structures, composed of tissue, that perform specific functions
osteoporosis loss of bone mass that causes bones to become lighter, more fragile and more easily broken
outer core the liquid outer layer of the core, which is about 2300 km thick
oxidation a chemical reaction involving the loss of electrons by a substance

oxygen an atom that forms molecules (O_2) of tasteless and colourless gas; it is essential for cellular respiration for most organisms and is a product of photosynthesis
oxygenated blood the bright red blood that has been supplied with oxygen in the lungs
P-waves or **primary waves** body seismic waves with a compressional (push-and-pull) motion; they are the fastest and first to arrive
pacemaker an electronic device inserted in the chest to keep the heart beating regularly at the correct rate; it works by stimulating the heart with tiny electrical impulses
palaeontologist a scientist who studies fossils
pancreas a large gland in the body that produces and secretes the hormone insulin and an important digestive fluid containing enzymes
Pangaea a supercontinent that existed about 299 to 200 million years ago; all landmasses were joined together to form it
Panthalassa the vast ocean surrounding the supercontinent of Pangaea
parallax error error caused by reading a scale at an angle rather than placing it directly in front of the eye
parallel circuit a circuit that has more than one path for electricity to flow through; if one of the paths has a break in it, the others will still work
percussion flaking a process in which tool stones, such as flint or obsidian, were struck with harder stones, such as quartzite, to shear large flakes off until they were a desired shape
period the time taken for one oscillation of a pendulum
periodic table a table listing all known elements; the elements are grouped according to their properties and in order of the number of protons in their nucleus
periodontal disease a serious gum infection that damages the soft tissue and bone that supports your teeth; it can lead to tooth loss if not treated
peristalsis the process of pushing food along the oesophagus or small intestine by the action of muscles
permineralisation the most common method of fossilisation, in which minerals fill the cellular spaces and crystallise; the shape of the original plant or animal is preserved in great detail
phloem a type of tissue that transports sugars made in the leaves to other parts of a plant
photosynthesis a series of chemical reactions that occur within chloroplasts in which the light energy is converted into chemical energy; the process also requires carbon dioxide and water, and produces oxygen and sugars, which the plant can use as 'food'
physical changes changes in which no new chemical substances are formed; a physical change may be a change in shape, size or state, and many of these changes are easy to reverse
physical properties properties that you can either observe using your five senses — seeing, hearing, touching, smelling and tasting — or measure directly
plasma the yellowish liquid part of blood that contains water, minerals, food and wastes from cells
plastic a synthetic substance capable of being moulded
plate tectonics a scientific theory that describes the relative movements and interaction of plates of Earth's crust over the underlying mantle
platelets small bodies involved in blood clotting; they are responsible for healing by clumping together around a wound
polyester a synthetic fibre; the monomers are joined together by the elimination of water molecules at the joins
polymer a substance made by joining smaller identical units; all plastics are polymers
pop test a test that uses a flame to test for the presence of hydrogen; a 'pop' sound will be heard on ignition if the gas has been produced
postulated to suggest an idea or theory
potential difference also known as voltage, is the change in the amount of energy stored in electrons as they move through a component or a circuit
potential energy energy stored within an object that depends on its position within a system, such as gravitational energy, elastic energy and chemical energy
power the rate at which energy is converted into other forms in a device
power supply a device that can provide an electric current

precipitate the new, solid product produced when reactants are mixed together; a precipitate is insoluble in water
precision how close multiple measurements of the same investigation are to one another
products new chemical substances that result from a chemical reaction; new chemical bonds are formed to make the products during a chemical reaction
proteases enzymes that break proteins down into amino acids
protein a chemical made up of amino acids needed for growth and repair of cells in living things
proton a tiny particle found in the centre (nucleus) of an atom; it has a positive electric charge
prokaryote any cell or organism without a membrane-bound nucleus (e.g. bacteria)
pulmonary artery the vessel through which deoxygenated blood, carrying wastes from respiration, travels from the heart to the lungs
pulmonary vein the vessel through which oxygenated blood travels from your lungs to the heart
pulse the alternating contraction and expansion of arteries due to the pumping of blood by the heart
pumice a glassy, pale igneous rock that forms when frothy rhyolite lava cools in the air; it often floats on water as it is very light and full of holes that once contained gas
qualitative data categorical data that examines the quality of something (e.g. colour or gender) rather than a measurement or quantity
quantitative data numerical data that examines the quantity of something (e.g. length or time)
quartzite an extremely compact and hard metamorphic rock consisting essentially of quartz
R-value shows how well a material stops heat from passing through it; a higher R-value means better insulation, keeping heat inside in winter and outside in summer
radiation energy transfer in the form of electromagnetic waves, that is, light (although this may be non-visible, such as infrared radiation)
radioactive refers to when atoms are unstable and emit a particle to remove excess energy; these particles are capable of ionising other atoms upon collision, which can cause harm to living tissue
random errors an error that occurs due to estimation when reading scales, or when the quantity being measured changes randomly
Rayleigh waves surface seismic waves that have a rolling motion
reactants chemical substances used in a chemical reaction; chemical bonds of the reactants are broken during a chemical reaction
reactivity a measure of how likely a particular substance reacts to make new substances
rectum the final section of the digestive system, where waste food matter is stored as faeces before being excreted through the anus
recycling reusing an unwanted substance or object for another purpose
red blood cells living cells in the blood that transport oxygen to all other living cells in the body
regenerated fibre a fibre produced after a natural material has been chemically treated in some way.
rehabilitation the restoration to its previous condition or an acceptable, agreed alternative
relative age the age of a rock compared with the age of another rock
renewable resources resources that are provided continuously, or naturally replaced over a period of months or years
reproductive system the different reproductive organs required by many organisms to reproduce and create offspring
resistance measure of the electrical energy required for an electric current to pass through an object, measured in ohms (Ω)
respiratory system the lungs and associated structures that are responsible for getting oxygen into the organism and carbon dioxide out
reverse fault a break where the rock above the fault moves 'up' due to compression
rhyolite a light-coloured, extrusive igneous rock with a similar mineral composition to granite, but with smaller crystals
ribosomes small structures within a cell in which proteins such as enzymes are made
Richter scale a logarithmic scale that measures the amount of energy released during an earthquake, thus allowing one earthquake to easily be compared to another

rift valley a sunken lowland between two normal faults; a graben
right atrium the upper-right section of the heart where deoxygenated blood from the body enters
right ventricle the lower-right section of the heart, which pumps deoxygenated blood to the lungs
rock cycle a cycle of processes that rocks experience in Earth's crust as they constantly change from one type to another
rock salt a sedimentary deposit formed when a salt lake or seabed dries up; the sediments are made of sodium chloride (halite)
Rube Goldberg machine a machine that is designed to perform a simple task in a complicated way
rust a red-brown substance formed when iron reacts with oxygen and water
rusting the corrosion of iron
S-waves or **secondary waves** body seismic waves with a transverse (up-and-down) motion; they are slower than P-waves and cannot travel through fluids
safety glasses plastic glasses used to protect the eyes during experiments
safety goggles like safety glasses but safer because they form a seal against the face
saliva a watery substance in the mouth that contains enzymes involved in the digestion of food
salivary glands glands in the mouth that produce saliva
sandstone a sedimentary rock with medium-sized grains; the sand grains are cemented together by silica, lime, mud or salts
Sankey diagram a visualisation of energy transfers, using arrows with width proportional to the amount of energy involved
scavenger an animal that eats dead plant and animal material
scientists people skilled in or working in the fields of science; scientists use experiments to find out about the material world around them
scientific method a systematic and logical process of investigation to test hypotheses and answer questions based on data or experimental observations
scoria a dark, igneous rock formed from frothy basalt lava that cools quickly and is full of holes that once contained gas
sea-floor spreading the formation of oceanic crust, which occurs by the rising and melting mantle at ocean ridges that push older crust away from the ridge
sediment material broken down by weathering and erosion that is moved by wind or water and collects in layers
sedimentary rocks rocks formed through the deposition and compaction of layered sediment
seismic waves waves released when rock breaks or is rapidly moved
seismograph an instrument used to detect and measure the intensity of an earthquake; also called a seismometer
seismologist a scientist who studies earthquakes to both understand how they work and how to better predict them
sensors input devices capable of measuring an environmental variable, such as temperature
series a formation of electricity-generating or electricity-using devices whereby the electricity passes from one device to the next in a single conducting loop, one after the other
series circuit a circuit with the components joined one after the other in a single continuous loop
shale a fine-grained sedimentary rock formed from thinly layered mud
shearing a smearing force
silicates a group of minerals consisting primarily of SiO_4^{2-} combined with metal ions, forming a major component of the rocks in Earth's crust
siltstone a sedimentary rock with a particle size between that of sandstone and mudstone
skin the external covering of a vertebrate's body
slate a fine-grained metamorphic rock formed as a result of moderate heat and pressure on shale
small intestine the part of the digestive system between the stomach and large intestine, where much of the digestion of food and absorption of nutrients takes place
smart homes dwellings that feature a network of internet-connected devices that can operate automatically or via user input
smart meters remote monitoring devices that measure and report on a household's electricity usage every 30 minutes

solute a dissolved substance in a solution
solvent the substance in which the solute is dissolved
spinneret a nozzle with small holes through which a plastic material passes, forming threads; also the organ used by spiders to create their webs
state the condition or phase of a substance; the three main states of matter are solid, liquid and gas
stem cells undeveloped cells found in blood and bone marrow that can reproduce themselves indefinitely
stereo microscope a type of binocular microscope through which the detail of larger specimens can be observed
stomach a large muscular organ that churns and mixes food with gastric juice to start to break down protein
stomata openings mainly on the lower surface of leaves; these pores are opened and closed by guard cells; singular = stoma
Stone Age a prehistoric time when weapons and tools were made of stone, bone or wood
strainmeter equipment that measures any change in the shape of Earth's crust
streak the colour of a mineral as a fine powder, found by rubbing it onto an unglazed white ceramic tile
strike-slip fault a break where the rocks on either side of the fault move horizontally due to shearing
subduction refers to a convergent plate boundary where one plate moves under another
subduction zone where old oceanic crust enters the mantle
super-efficient appliances household appliances that receive an Energy Rating of over 6 stars
surface protection refers to when a protective coating is applied over a metal surface to prevent corrosion
surface waves seismic waves that travel slower than body waves and only along the surface of Earth; their energy is lost with depth and distance
suspension a mixture in which solid substances do not dissolve and are dispersed throughout the volume of the liquid
sustainable describes the concept of using Earth's resources so that the needs of the world's present population can be met, without damaging the ability of future populations to meet their needs
switch device that opens and closes the conducting path through which a current flows
syncline a fold in a rock with the narrow point facing downwards
systematic errors errors that are consistently high or low due to the incorrect use or limitations of equipment
systolic pressure the higher blood pressure reading during contraction of the heart muscles
tectonic plates large pieces of Earth's outer layer (the crust) that move slowly over time; their movement causes earthquakes, volcanoes and the formation of mountains
teeth hard structures within the mouth that allow chewing
tension a stretching force
thermistors a type of resistor that changes its resistance depending on temperature; it is used in things such as thermostats
testable able to be supported or proven false through the use of observations and investigation
test tube a thin glass container for holding, heating or mixing small amounts of substances
tiltmeter equipment that measures changes in the angle of the ground
tinder light, dry material that is easy to ignite
tissue a group of cells of similar structure that perform a specific function
toxicity the danger to your health caused when poisonous substances combine with chemicals in your body to produce new substances with damaging effects
trace fossils fossils that provide evidence, such as footprints, that an organism was present when the rock was formed
trachea the narrow tube from the mouth to the lungs through which air moves
transducer a device that converts energy from one form into another form
transform in energy terms, this refers to the changing of one form of energy into another
transform boundary where two tectonic plates slide past one another
translocation the process in which sugars and amino acids are transported within a plant by phloem tissue
transpiration the loss of water from plant leaves through their stomata
transpiration stream the movement of water through a plant as a result of loss of water from the leaves
transfer in energy terms, the movement of energy from one place to another

tremors minor vibrations of the ground that are commonly not felt
tsunami a powerful ocean wave triggered by an undersea earth movement
turgid refers to cells that are firm
U-value shows how easily heat moves through a material; a lower U-value means the material loses less heat, making it better for insulation
underground mining mining that uses shafts and tunnels to remove rock from deep below the surface
unicellular made up of only one cell
urea a nitrogen-containing substance produced by the breakdown of proteins and removed from the blood by the kidneys
ureters tubes from each kidney that carry urine to the bladder
urethra the tube through which urine is emptied from the bladder to the outside of the body
uric acid a nitrogenous waste product of protein breakdown
urination the passing of urine from the bladder to the outside of the body
urine a yellowish liquid, produced in the kidneys; it is mostly water and contains waste products from the blood such as urea, ammonia and uric acid
useful energy the energy that produces the desired output
vacuoles sacs within a cell used to store food and wastes; plant cells usually have one large vacuole, while animal cells have several small vacuoles or none at all
valid describes how accurately a method measures what it is intended to measure, and how appropriate it is in addressing the aim of the experiment; a valid conclusion can be supported by other scientific investigations
valves flap-like folds in the lining of a blood vessel or other hollow organ that allow a liquid, such as blood, to flow in one direction only
variable resistor a device that can change how much it resists the flow of electricity; it is used to control things such as volume or brightness
variables quantities or conditions in an experiment that can change
varicose veins expanded or knotted blood vessels close to the skin, usually in the legs; they are caused by weak valves that do not prevent blood from flowing backwards
vascular bundles groups of xylem and phloem vessels within plant stems
veins blood vessels that carry blood back to the heart; they have valves and thinner walls than arteries
vena cava the large vein leading into the top-right chamber of the heart
venules small veins
villi tiny, finger-like projections from the wall of the intestine that maximise the surface area of the structure to increase the efficiency of nutrient absorption; singular = villus
viscosity a measure of a fluid's resistance to flow
visible spectrum different colours that combine to make up white light; they are separated in rainbows
vital capacity the largest volume of air that can be breathed in or out at one time
vitamin D a nutrient that regulates the concentration of calcium and phosphate in the bloodstream and promotes the healthy growth and remodelling of bone
volcanic arc a chain of volcanoes, typically curved, formed above a subduction zone
volcanic bomb refers to when a large rock fragment that falls from an eruption, formed as lava, is blown out of a volcano and is rapidly cooled in the air
volcano a landscape feature through which melted rock is erupted onto Earth's surface
voltage the amount of energy that is pushing electrons around a circuit, per coulomb of charge that flows between two points; the electromotive force making charged particles move around a circuit
voltmeter device used to measure the voltage across a component in a circuit; voltmeters are placed in parallel with the components
vomiting the forceful ejection of matter from the stomach through the mouth
weathering the physical or chemical breakdown of rocks on the surface
wilt refers to when plant stems and leaves droop due to insufficient water in their cells
white blood cells living cells that fight bacteria and viruses as part of the human body's immune system
xylem vessels pipelines for the flow of water up plants, made up of the remains of dead xylem cells fitted end to end with the joining walls broken down; lignin in the cell walls gives them strength

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