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SCIENCE

OXFORD SCIENCE 9

HELEN SILVESTER

SECOND EDITION

AUSTRALIAN CURRICULUM

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OXFORD UNIVERSITY PRESS

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

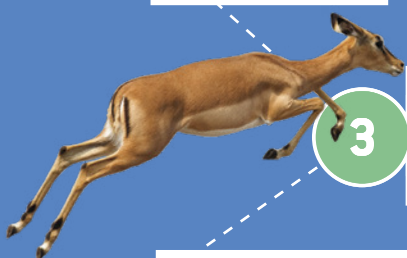
OXFORD SCIENCE 9

1 Science toolkit

Scientists work collaboratively and individually to design experiments. They control variables and use accurate measurement techniques to collect data. They consider ethics and safety. They analyse data, identify trends and relationships, and reveal inconsistencies in results. They analyse and evaluate their own and others' investigations.

2 Control and regulation

Multicellular organisms, such as humans, have systems that respond to changes in their environments. Receptors detect these changes and pass the information to other parts of the organism.



3 Reproduction

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

4 Subatomic particles

Matter is made of atoms. Atoms are systems of protons, neutrons and electrons. Radioactivity occurs when the nucleus of an unstable atom decays.

5 Chemical reactions

Different types of reactions are used to produce a range of products and can occur at different rates. Different factors influence the rates of reactions.

6 The carbon cycle

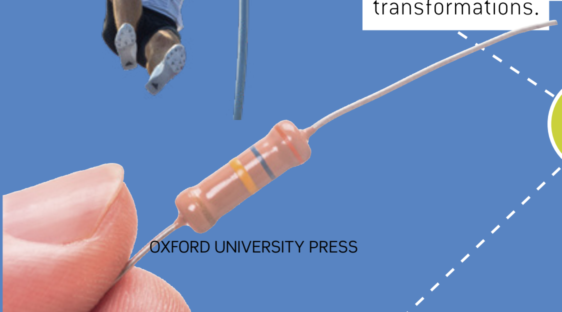
There are interactions and cycles within and between Earth's spheres. Global systems, including the carbon cycle, rely on these interactions involving the biosphere, lithosphere, hydrosphere and atmosphere.

7 Particles and waves

The transfer of heat energy is caused by the motion of particles. Sound is caused by the vibration of particles moving in a wavelike motion. Electricity is the presence and flow of charged particles. The electromagnetic spectrum is a way of describing all the different forms of light, including the light we see.

8 Energy efficiency

Energy cannot be created or destroyed. Sankey diagrams are used to represent the efficiency of energy transfers and transformations.



9 Experiments

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CONTENTS

INTRODUCING *OXFORD SCIENCE 7–10* AUSTRALIAN CURRICULUM

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

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

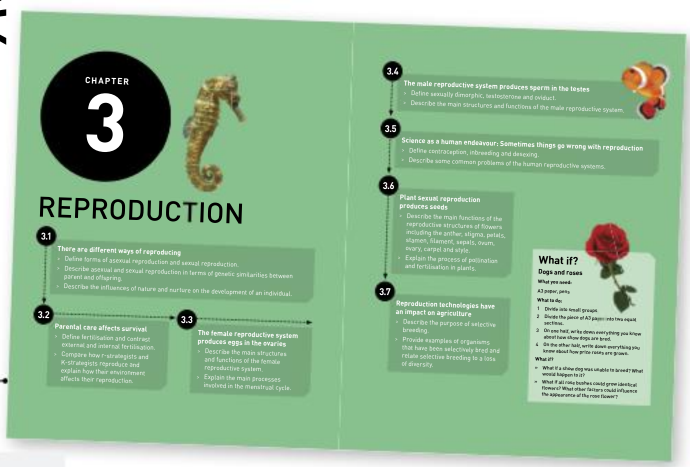
> Student Book   > Student obook pro   > Teacher obook pro.

Key features of this Student Book

> This Student Book combines complete curriculum coverage with clear and engaging design.

> Each print Student Book comes with complete access to all the digital resources available on Student obook pro.

Focus on concept development

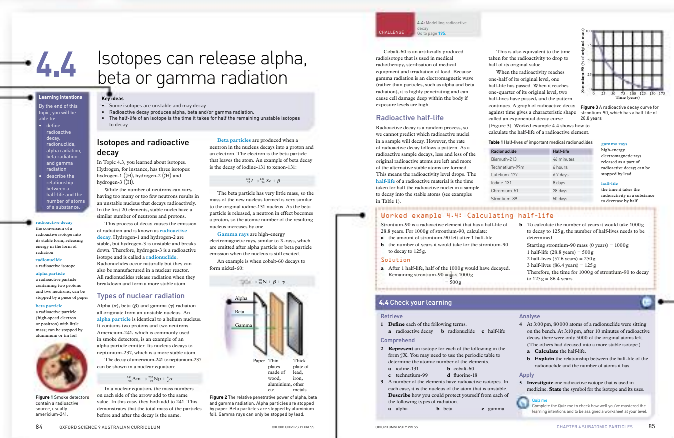


Reflect

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

Chapter openers

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



Concept statements

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

Learning intentions

- Learning intentions are clearly stated for every topic.

Key ideas

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

Margin glossary terms

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

Worked examples

- Students are provided with step-by-step worked examples for mathematical problems and scientific concepts.

Check your learning

- Each topic finishes with a set of 'Check your learning' questions that are aligned to the learning intentions for the topic. Questions are phrased using bolded cognitive verbs, which state what is expected of a student and prepares them for studying senior science subjects.

Focus on science inquiry skills and capabilities

Digital hotspots

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

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

Science toolkit

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

Science as a human endeavour

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

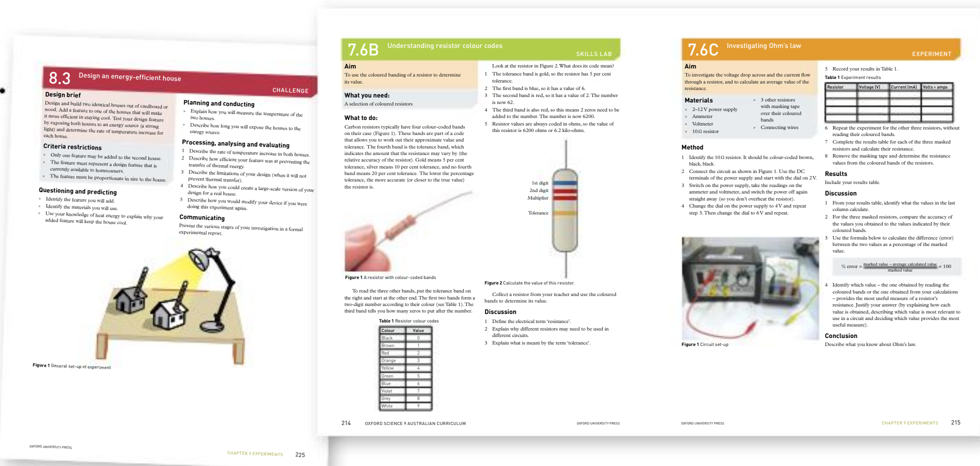
Test your skills and capabilities

- This section provides scaffolded opportunities for students to apply their science understanding while developing skills and capabilities.

Focus on practical work

Practical work appears at the back of the book

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



Challenges, Skills labs and Experiments

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

Focus on STEAM

Integrated STEAM projects

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

Problem solving through design thinking

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

Full digital support

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

Key features of Student obook pro

obook pro

> Student obook pro is a completely digital product delivered via Oxford's online learning platform, **Oxford Digital**.

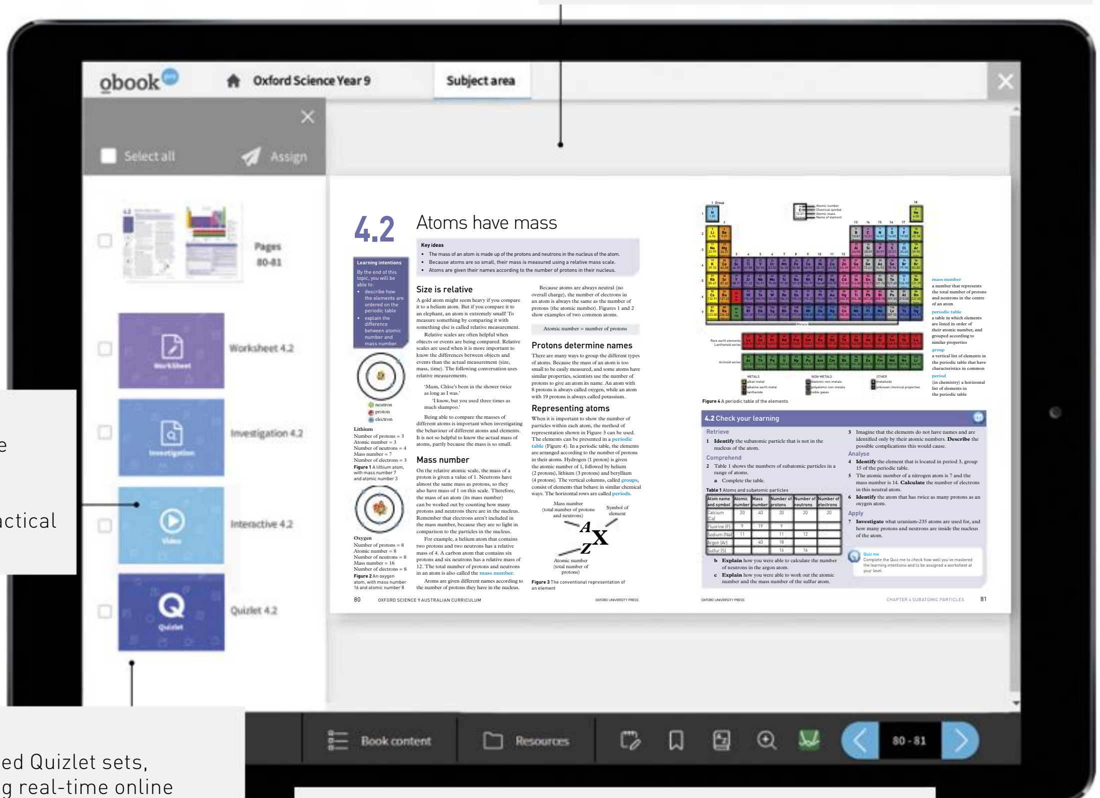
> It offers a complete digital version of the Student Book with interactive note-taking, highlighting and bookmarking functionality, allowing students to revisit points of learning.

> A complete ePDF of the Student Book is also available for download for offline use and read-aloud functionality.

Focus on eLearning

Complete digital version of the Student Book

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



Videos

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

Quizlet

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

Interactive quizzes

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

Benefits for students

> integrated *Australian Concise Oxford Dictionary* look-up feature

> targeted instructional videos for key concepts, practicals and worked examples

> interactive assessments to consolidate understanding

> integrated Quizlet sets, including real-time online quizzes with live leaderboards

> access to their online assessment results to track their own progress.

oxforddigital

Key features of Teacher obook pro

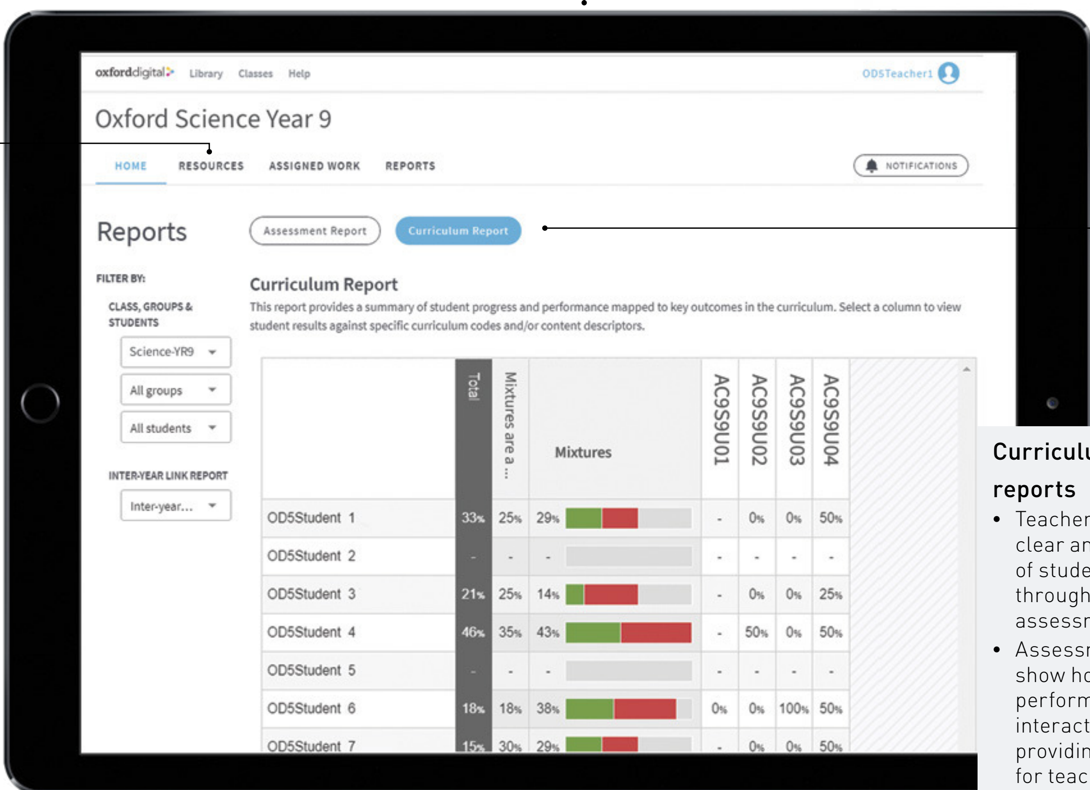
obook pro

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

Focus on assessment and reporting

Complete teaching support

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



Curriculum and assessment reports

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

Additional resources

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

Benefits for teachers

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

AUSTRALIAN CURRICULUM: SCIENCE 9 SCOPE AND SEQUENCE

YEAR 9 DESCRIPTION

In Year 9, students consider the operation of systems at a range of scales and how those systems respond to external changes in order to maintain stability. They explore ways in which the human body system responds to changes in the external environment through physiological feedback mechanisms and the reproductive processes that enable a species to respond to a changing environment over time. They are introduced to the notion of the atom as a system of protons, electrons and neutrons, and how this system can change through nuclear decay. They learn that matter can be rearranged through chemical change and that these changes play an important role in many systems. They are introduced to the concepts of conservation of matter and energy and begin to develop a more sophisticated view of energy transfer. They explore these concepts as they relate to the global carbon cycle. Students begin to consider how well a sample or model represents the phenomena under study and use a range of evidence to support their conclusions.

YEAR 9 CONTENT DESCRIPTIONS	
SCIENCE UNDERSTANDING	
Biological sciences	
Chapter 2	Compare the role of body systems in regulating and coordinating the body's response to a stimulus, and describe the operation of a negative feedback mechanism (AC9S9U01)
Chapter 3	Describe the form and function of reproductive cells and organs in animals and plants, and analyse how the processes of sexual and asexual reproduction enable survival of the species (AC9S9U02)
Earth and space sciences	
Chapter 6	Represent the carbon cycle and examine how key processes including combustion, photosynthesis and respiration rely on interactions between Earth's spheres (the geosphere, biosphere, hydrosphere and atmosphere) (AC9S9U03)
Physical sciences	
Chapter 7	Use wave and particle models to describe energy transfer through different mediums and examine the usefulness of each model for explaining phenomena (AC9S9U04)
Chapter 8	Apply the law of conservation of energy to analyse system efficiency in terms of energy inputs, outputs, transfers and transformations (AC9S9U05)
Chemical sciences	
Chapter 4	Explain how the model of the atom changed following the discovery of electrons, protons and neutrons and describe how natural radioactive decay results in stable atoms (AC9S9U06)
Chapter 5	Model the rearrangement of atoms in chemical reactions using a range of representations, including word and simple balanced chemical equations, and use these to demonstrate the law of conservation of mass (AC9S9U07)
SCIENCE AS A HUMAN ENDEAVOUR	
Nature and development of science	
All chapters	Explain how scientific knowledge is validated and refined, including the role of publication and peer review (AC9S9H01)
All chapters	Investigate how advances in technologies enable advances in science, and how science has contributed to developments in technologies and engineering (AC9S9H02)
Use and influence of science	
All chapters	Analyse the key factors that contribute to science knowledge and practices being adopted more broadly by society (AC9S9H03)
All chapters	Examine how the values and needs of society influence the focus of scientific research (AC9S9H04)

SCIENCE INQUIRY	
Questioning and predicting	
All chapters	Develop investigable questions, reasoned predictions and hypotheses to test relationships and develop explanatory models (AC9S9I01)
Planning and conducting	
All chapters	Plan and conduct valid, reproducible investigations to answer questions and test hypotheses, including identifying and controlling for possible sources of error and, as appropriate, developing and following risk assessments, considering ethical issues, and addressing key considerations regarding heritage sites and artefacts on Country/Place (AC9S9I02)
All chapters	Select and use equipment to generate and record data with precision to obtain useful sample sizes and replicable data, using digital tools as appropriate (AC9S9I03)
Processing, modelling and analysing	
All chapters	Select and construct appropriate representations, including tables, graphs, descriptive statistics, models and mathematical relationships, to organise and process data and information (AC9S9I04)
All chapters	Analyse and connect a variety of data and information to identify and explain patterns, trends, relationships and anomalies (AC9S9I05)
Evaluating	
All chapters	Assess the validity and reproducibility of methods and evaluate the validity of conclusions and claims, including by identifying assumptions, conflicting evidence and areas of uncertainty (AC9S9I06)
All chapters	Construct arguments based on analysis of a variety of evidence to support conclusions or evaluate claims, and consider any ethical issues and cultural protocols associated with accessing, using or citing secondary data or information (AC9S9I07)
Communicating	
All chapters	Write and create texts to communicate ideas, findings and arguments effectively for identified purposes and audiences, including selection of appropriate content, language and text features, using digital tools as appropriate (AC9S9I08)

YEAR 9 ACHIEVEMENT STANDARD

By the end of Year 9, students explain how body systems provide a coordinated response to stimuli. They describe how the processes of sexual and asexual reproduction enable survival of the species. They explain how interactions within and between Earth's spheres affect the carbon cycle. They analyse energy conservation in simple systems and apply wave and particle models to describe energy transfer. They explain observable chemical processes in terms of changes in atomic structure, atomic rearrangement and mass. Students explain the role of publication and peer review in the development of scientific knowledge and explain the relationship between science, technologies and engineering. They analyse the different ways in which science and society are interconnected.

Students plan and conduct safe, reproducible investigations to test or identify relationships and models. They describe how they have addressed any ethical and intercultural considerations when generating or using primary and secondary data. They select and use equipment to generate and record replicable data with precision. They select and construct appropriate representations to organise, process and summarise data and information. They analyse and connect data and information to identify and explain patterns, trends, relationships and anomalies. They analyse the impact of assumptions and sources of error in methods and evaluate the validity of conclusions and claims. They construct logical arguments based on evidence to support conclusions and evaluate claims. They select and use content, language and text features effectively to achieve their purpose when communicating their ideas, findings and arguments to specific audiences.

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Chapter 3: REDA &CO srl/Alamy Stock Photo, p.58 fig 3; Nature Picture Library/Alamy Stock Photo, p.61 fig 3; imageBROKER/Alamy Stock Photo, p.61 fig 4; Auscape International Pty Ltd/Alamy Stock Photo, p.65 fig 2(a); Karin Duthie/Alamy Stock Photo, p.65 fig 2(b); agefotostock/Alamy Stock Photo, p.65 fig 2(c); Avalon.red/Alamy Stock Photo, p.65 fig 4; Science Photo Library/Alamy Stock Photo, p.66 fig 1; Philip Game/Alamy Stock Photo, p.67 fig 2; keith burdett/Alamy Stock Photo, p.69 fig 6; Dave Watts/Alamy Stock Photo, p.71 fig 3; Avalon.red/Alamy Stock Photo, p.73 fig 6; Shutterstock, p.56, p.57 (all), p.58 fig 1, p.58 fig 2, p.58 fig 4, p.59 fig 5, p.59 fig 6, p.62 top, p.63 fig 2, p.65 fig 3, p.67 fig 3, p.67 fig 4, p.69 fig 5, p.70 fig 1, p.71 fig 2, p.71 fig 4, p.71 fig 5, p.73 fig 5, p.73 fig 5, p.60 fig 1, p.60 fig 2, p.72 fig 1, p.74 fig 7, p.74 fig 8.

Chapter 4: Science Photo Library/Alamy Stock Photo, p.84 fig 1; Ism/Science Photo Library, p.89 fig 3; Science Photo Library/Alamy Stock Photo, p.89 fig 4; Dr Damien Finch, p.86 fig 2; Robbie Shone/Science Photo Library, p.92 fig 6; Shutterstock, p.76, p.77 top, p.77 bottom, p.82 fig 3, p.86 fig 1, p.87 fig 3, p.87 fig 4, p.88 fig 2, p.91 fig 4, p.92 fig 5.

Chapter 5: Phil Degginger/Alamy Stock Photo, p.98 fig 1; Phil Degginger/Science Photo Library, p.95 top left, p.101 fig 3; Mike Greenslade, VW Pics/Science Photo Library, p.101 fig 2; Michael Szoenyi/Science Photo Library, p.101 fig 4; Shutterstock, p.94, p.95 top right, p.95 bottom, p.98 fig 2, p.105 fig 1(b), p.105 fig 1(a), p.106 fig 1, p.106 fig 2, p.107 fig 3, p.107 fig 4, p.107 fig 5, p.107 fig 6, p.108 fig 7, p.108 fig 8, p.108 fig 9.

Chapter 6: Danita Delimont/Alamy Stock Photo, p.114 fig 3; NOAA/SCIENCE PHOTO LIBRARY, p.119 fig 5; THE AGE/Craig Abraham, p.120 fig 2; Marco Taliani de Marchio/Alamy Stock Photo, p.122 fig 1; CSIRO, p.123 fig 3; Steve Bloom Images/Alamy Stock Photo, p.125 fig 3; John Chumack/Science Photo Library, p.109 top right, p.132 fig 6; Shutterstock, p.108 bottom, p.109 bottom, p.115 fig 5, p.117 fig 2, p.118 fig 3, p.118 fig 4, p.119 fig 6, p.120 fig 1, p.121 fig 3, p.123 fig 2, p.128 fig 1, p.129 fig 3, p.129 fig 3, p.129 fig 3, p.129 fig 2, p.130 fig 1, p.131 fig 2, p.132 fig 4.

Chapter 7: NASA/Johnson Space Center, p.140 fig 1; Science Photo Library/Alamy Stock Photo, p.140 fig 2; Science Photo Library/Alamy Stock Photo, p.141 fig 4; David R. Frazier Photolibrary, Inc./Alamy Stock Photo, p.142 fig 2; sciencephotos/Alamy Stock Photo, p.147 fig 4; Scott Camazine/Alamy Stock Photo, p.151 fig 3(a); amana images inc./Alamy Stock Photo, p.153 fig 3; Photo Provider Network/Alamy Stock Photo, p.156 fig 2; Shutterstock, p.134 top, p.135, p.149 fig 3, p.141 fig 3, p.143 fig 4 (a), p.143 fig 4 (b), p.144 fig 2, p.145 fig 3, p.146 fig 2, p.147 fig 3, p.151 fig 3(b), p.151 fig 4, p.152 fig 1, p.154 fig 1, p.155 fig 5, p.158 fig 2, p.159 fig 3, p.159 fig 4, p.160 fig 5, p.160 fig 6.

Chapter 8: Alice Mora and Maurizio Campanelli, p.168 fig 1; PCN Photography/Alamy Stock Photo, p.171 fig 3; Shutterstock, p.162, p.163 (all), p.165 fig 2, p.165 fig 3, p.169 fig 2, p.169 fig 3, p.174 fig 4, p.174 fig 5.

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Contents, glossary and index: Karin Duthie/Alamy Stock Photo, p. iii (2); Phil Degginger/Alamy Stock Photo, p. iii (5); PCN Photography/Alamy Stock Photo, p. iii (8); Shutterstock, p.iii (1), p.iii (3), p.iii (5), p.iii (6), p.iii (9), p.v (all), p.234 (all), p.239, p.240 (all), p.244.

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CHAPTER

1

SCIENCE TOOLKIT

1.1

Scientists can test manufacturers' claims

- Explain the differences between variables, the independent variable and the dependent variable, in terms of what is controlled, changed or measured.
- Describe how sample size and repetition affects the reliability of a test.
- Write a scientific report with all relevant sections.

1.2

Scientists must be aware of experimental errors

- Define accuracy and uncertainty.
- Identify the correct equipment to use to get an accurate measurement.
- Describe how experimental errors can affect the outcome of an experiment.

1.3

Scientists prepare Safety Data Sheets

- > Describe the purpose of Safety Data Sheets and provide examples of some of the types of information included on them.

1.4

Scientific data must be validated

- > Describe factors that affect the validity of an experiment.
- > Identify the validity of secondary sources.
- > Explain why extrapolating data can introduce errors.

1.5

Science as a human endeavour: Scientists investigate consumer products

- > Describe the factors involved in designing a valid experiment and explain how to increase the reliability of results.
- > Provide examples of common errors that should be minimised or avoided.
- > Present data in an appropriate manner.

1.6

Cognitive verbs identify the tasks in a question

- > Recognise the cognitive verb in a question.
- > Understand the different tasks involved for different cognitive verbs.

What if?

Staples

What you need:

Ten sheets of A4 paper, a stapler with staples

What to do:

1 Fold an A4 sheet of paper in two.

2 Staple the two halves of paper together with the stapler.

3 Add another sheet of paper to the folded paper so that there are now three sheets over the top of each other.

4 Staple all the sheets together with the stapler.

5 Repeat steps 3 and 4 until the stapler is unable to penetrate all the sheets of paper effectively.

What if?

» What if another stapler was used?

» What if another brand of staples was used?

» What if different paper was used?

1.1 Scientists can test manufacturers' claims

Learning intentions

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

- explain the differences between variables, the independent variable and the dependent variable, in terms of what is controlled, changed or measured
- describe how sample size and repetition affects the reliability of a test
- write a scientific report with all relevant sections.

Key ideas

- The scientific method involves forming a hypothesis, planning an experiment that controls the variables, gathering data, analysing results, drawing a conclusion and communicating the results.
- Consumer science is a branch of science that involves applying the scientific method to the claims made by manufacturers.

No matter what you buy – toilet paper, a smartphone or a bottle of water – you are a consumer. As a consumer you make choices and you expect certain things from the products you buy.

Consumer science case study

In 2004, two New Zealand science students, Jenny Suo and Anna Devathasan, exposed a startling fact about the fruit juice drink Ribena while conducting research for their school's science fair. Jenny and Anna decided to compare the vitamin C content of different fruit juice drinks to see if the manufacturer's claims on the labels were correct. The label on Ribena, which contains blackcurrant juice, implied that it had a much higher vitamin C content than the other fruit juice drinks they tested.

Figure 1 Jenny Suo and Anna Devathasan

It said: 'The blackcurrants in Ribena contain four times the vitamin C of oranges'. The students therefore predicted that Ribena would have four times the vitamin C content of orange fruit juice drinks.

Jenny and Anna developed a test for the vitamin C content of Ribena and several other fruit juice drinks, using the scientific method. They ensured that their tests were **valid** and **reproducible**. This meant that they needed to use a test that identified the amount of vitamin C in a liquid (that is, the claim they were testing) and that it could be repeated many times to achieve the same results. They controlled all variables in the tests. The only difference between their repeated tests was the brands. Jenny and Anna repeated the test three times to ensure the precision of their results. After each trial, they re-examined their data to make sure that the results were similar to previous trials and to check if there were other variables that they needed to control.

The students were surprised to find that the vitamin C content of Ribena was far lower than most other brands. But because they had followed the scientific method, they were confident that their results were reliable. For this reason, they contacted the manufacturer about the misleading labelling and advertising. When no response was received, they brought their case to a national consumer affairs program.

After their case was broadcast, and after further testing of Ribena, the New Zealand Commerce Commission brought 15 charges against the manufacturer under the *Fair Trading Act 1986* (NZ).

valid
where a test investigates what it sets out to investigate

reproducible
the ability to repeat and replicate a test exactly

EXPERIMENT
1.1: What if the absorbency of different paper towels was compared?
Go to page **178**.

Figure 2 Ribena was found to contain less vitamin C than its competition, despite the manufacturer's claims.

The scientific method at work

Jenny and Anna were sure of their results because they followed the scientific method. Figure 3 shows the stages of the scientific method. Several stages of the scientific method are described in a formal scientific report of the investigation.

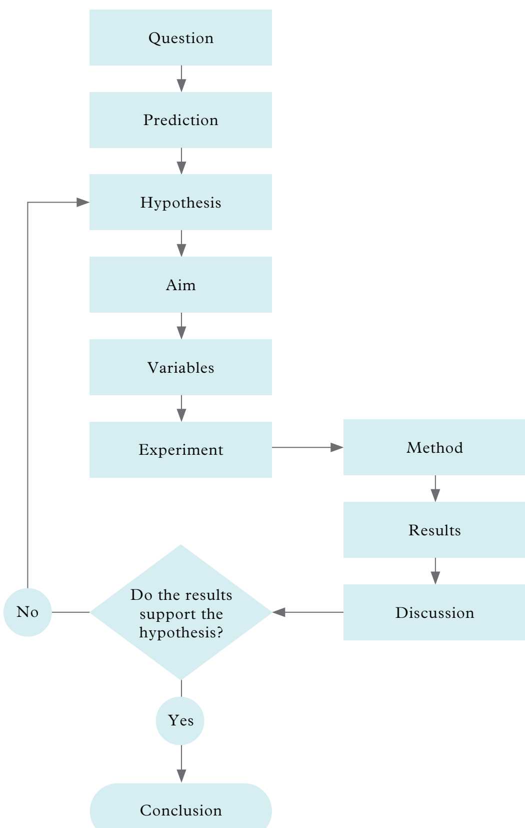


Figure 3 The scientific method

Hypothesis

The scientific method involves developing a plan to test a hypothesis that can come from a 'what if' question. For Jenny and Anna, this question was:

'*What if* the vitamin C content of Ribena was compared with other fruit juice drinks?'

This then became a prediction using the words 'if' and 'then':

'*If* the vitamin C content of Ribena is compared with other fruit juice drinks, *then* Ribena will have more vitamin C per millilitre.'

A hypothesis should also include the idea or theory on which the prediction is based. This is done through the use of 'because':

'*If* the vitamin C content of Ribena is compared with other fruit juice drinks, *then* Ribena will have more vitamin C per millilitre *because* blackcurrants have a greater vitamin C content than other fruits.'

A hypothesis should be based on some underlying suspicion, prediction or idea that is based on previous observations. It must be very specific (operational) so that it can be tested.

Variables

A hypothesis should be tested in an objective way. For example, for a fair comparison of the fruit juice drinks, Jenny and Anna needed to design an experiment that identified all the **variables** that would be operating. The variables in an experiment are the factors that will affect the results in some way. These could include the volume of the fruit juice drinks tested, and the age and temperature of the fruit juice drinks.

To test the hypothesis, all the variables should be controlled except for the one being tested. This is known as the **independent variable**, and in Jenny and Anna's case it was the brand of the fruit juice drink being tested. The variable being measured at the end of the experiment is the **dependent variable**, in this case, the amount of vitamin C in a fruit juice drink. Figure 4 on page 6 shows the the variables in Jenny and Anna's investigation.

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

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

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

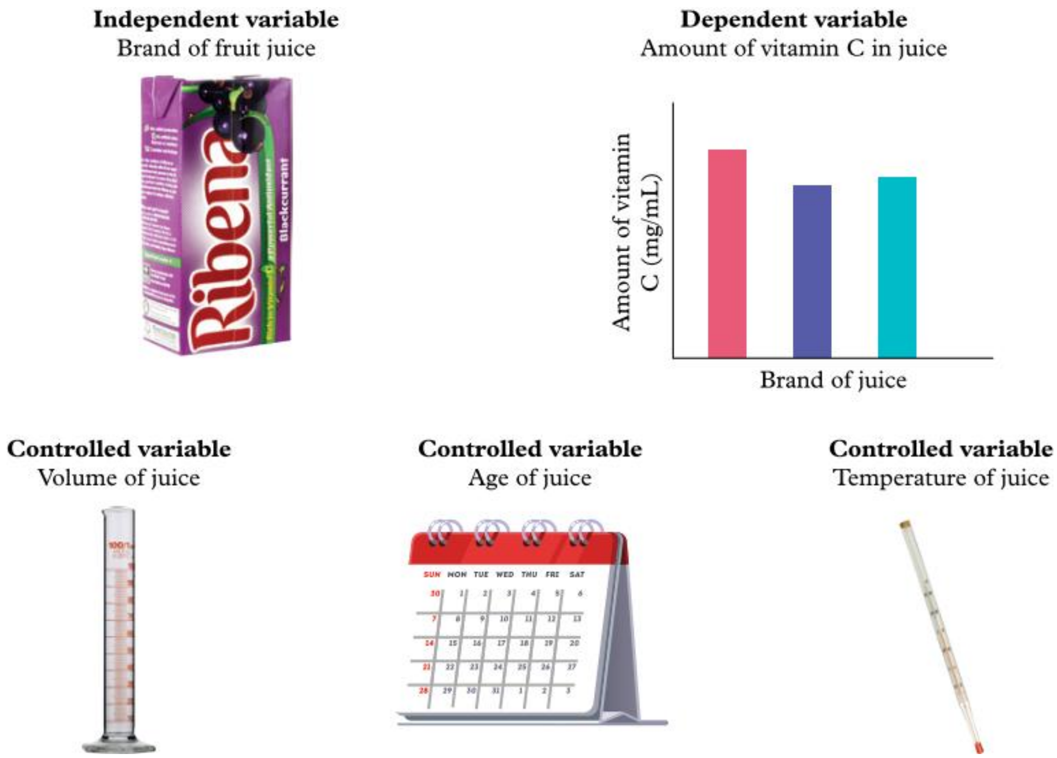


Figure 4 The variables in the experiment

Method

In this section, a scientist describes the materials and equipment they used, including the concentrations and brands they tested. Diagrams are also useful to illustrate the steps taken. Remember to label all equipment in the diagram and to give the diagram a title.

The number of times you repeat an entire experiment is referred to as repetition. The more times an experiment is repeated to obtain an average, the more likely it is that the results are reliable.

The **sample size** refers to the number of subjects being tested or used in the experiment. The greater the sample size, the more reliable the results will be and the stronger the evidence available to support the conclusion.

sample size
the number of subjects being tested or used in an experiment

correlated
when results in an experiment show that independent and dependent variables are related

Results

The observations you make, or the data you collect, during your experiment are written down as the results.

All observations should be what you actually see and not what you expect to see. Data can be organised into a table format and/or a graph to make it easier to understand.

Discussion

Once all the results have been gathered, they need to be analysed for any patterns that show if the independent variable and the dependent variable changed in a similar way. If they did, this means the results are **correlated**.

Conclusion

A conclusion answers the initial question asked about the experiment. It provides evidence that supports or refutes the hypothesis. Any further investigations that may need to be done are outlined in this section.

Figure 5 summarises the steps Jenny and Anna took to test the Ribena manufacturer's claim using the scientific method.

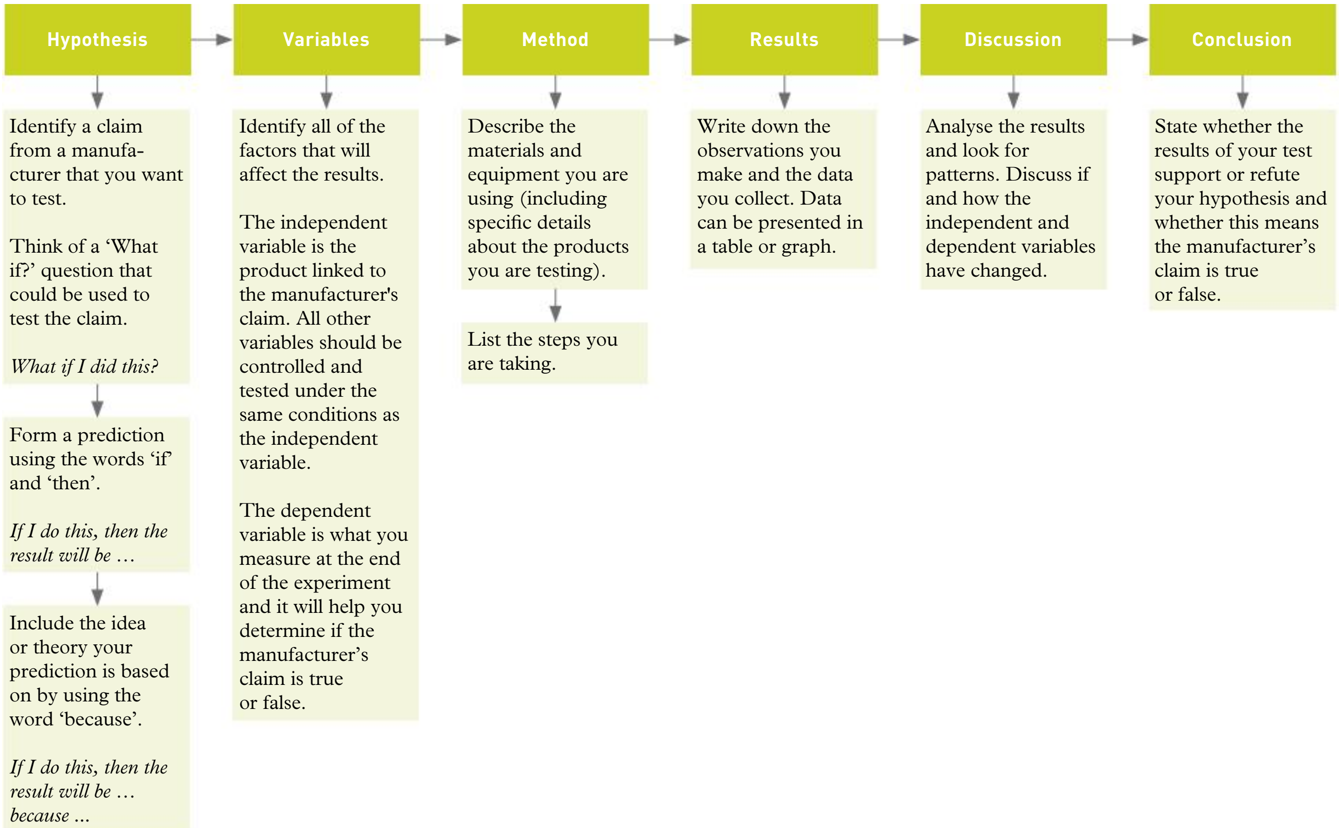


Figure 5 Testing a manufacturer's claim using the scientic method

1.1 Check your learning

Retrieve

1 **Define** the term 'hypothesis'.

Comprehend

2 **Explain** why an experiment should have a clear and detailed method.

Analyse

3 **Consider** the following statement:
'If participants in Group A use Brand A toothpaste for six weeks, then they will have whiter teeth than participants in Group B, who used Brand B toothpaste for six weeks.'
  a **Identify** what is missing from this statement to make it a hypothesis.
  b **Identify** the independent and dependent variables being tested.
  c **Identify** one controlled variable in the experiment. **Explain** why it is important for this variable to be controlled.

Apply

4 **Describe** how a hypothesis that is shown to be wrong can still be useful. **Justify** your answer (by providing an example that matches your description).

5 **Evaluate** the claim that 'an increased sample size makes an experiment more reliable'. **Justify** your answer by:
> defining the terms 'sample size' and 'reliable'
> explaining the effect of increasing the sample size in an experiment
> deciding whether increasing the sample size makes an experiment more reliable.

6 Scientists often have to present their findings to the public in order to get action taken. Sometimes this is difficult, so they need to be sure that their findings are reliable. **Discuss** how the scientific method ensures that the findings are valid by:
> defining the terms 'independent variable' and 'dependent variable'
> describing the importance of controlling all other variables
> identifying why it is important for the method to be repeatable.

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

1.2 Scientists must be aware of experimental errors

Learning intentions

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

- define accuracy and uncertainty
- identify the correct equipment to use to get an accurate measurement
- describe how experimental errors can affect the outcome of an experiment.

Key ideas

- In scientific investigation, measurements can only show that a hypothesis is correct if the measurements are accurate.
- To achieve maximum accuracy, the measurement must be taken carefully, using the most suitable measuring device.
- Each scientific device must have a scale appropriate to the accuracy that you require.

Choosing the right device

Choosing the right instrument is the first step in making sure the measurements are close to the expected true value (**accurate**). For example, if you needed to accurately measure the volume of a liquid, then you would use a burette or a measuring cylinder, but not a beaker. A beaker usually has a few general marks on the side of the container as an approximation of the volume. A measuring cylinder has many more marks that are closer together. This is a more accurate scale with less approximation of volumes than given by the marks on a beaker. A burette has more marks closer together than a measuring cylinder. A burette's scale is more accurate than a measuring cylinder's.

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

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

Figure 2 Traditional scales relied on the scientist's judgement of the top bar being horizontal.

There are many different ways to measure the mass of a sample. Traditionally, a set of scales was used with weights on one side and the substance on the other. Scientists who used these devices needed to estimate when the top of the scale was horizontal in order to have an accurate measurement.

Before a scale was used, the scientist would check that the top of the scale was horizontal when no weights were used. Today, scientists use digital balances to measure the mass of a substance. They still check that the scale is 'zeroed' before their sample is added. This is done by selecting TARE and checking that the reading is 0.00. If this is not done, then every measurement will be inaccurate.

Depending on the scale, the measurements may be accurate to 2, 3 or 4 decimal places. It is always important to write down all the significant figures that are provided by the measuring devices.

Uncertainties

Sometimes the amount that is being measured is between two values. This can happen when measuring the volume in a measuring cylinder. For example, the bottom of a meniscus is between 4.4 mL and 4.6 mL. While most people would estimate the volume as 4.5 mL, a scientist needs to show the level of **uncertainty** in the value. When this occurs, the volume should be recorded as 4.5 ± 0.1 mL. This means the volume could be any value between 4.4 and 4.6 mL.

When the different measurements are combined, the amount of uncertainty is also combined.

uncertainty
a quantitative measurement of variability in data

Worked example 1.2A: Adding uncertainties

Ali was adding two liquids together. They measured the first volume as 5.5 ± 0.1 mL and the second value as 7.3 ± 0.2 mL. Calculate the final volume of the liquids when they were added together.

Solution

When adding values, the uncertainties should also be added.

5.5 ± 0.1 mL + 7.3 ± 0.2 mL
= (5.5 + 7.3) ± (0.1 + 0.2) mL
= 12.8 ± 0.3 mL

The level of uncertainty can also be shown when there are many different measurements taken during an experiment. For example, an experiment that measured the amount of time it took for a ball to fall from the table to the floor may have slightly different numbers depending on how quickly the scientist stopped the stopwatch (3.3 seconds, 3.6 seconds, 3.0 seconds). In previous years, you may have calculated the mean of the times (3.3 seconds). A scientist should also provide the level of uncertainty of this value (3.3 ± 0.3 seconds) to show the highest and lowest values measured.

Worked example 1.2B: Calculating uncertainties

A class was measuring the height of seedlings that were given fertiliser. Their results are shown in the table below.

Seedling	Growth (cm)
1	1.3
2	2.1
3	1.4
4	1.4
5	2.3
6	1.1
7	1.9

Calculate the mean growth (including the uncertainty) of the seedlings.

Solution

First calculate the mean of the data.

$$\textit{Mean seedling growth} = \frac{\textit{Sum of seedling heights}}{\textit{number of seedlings}}$$

$$= \frac{1.3 + 2.1 + 1.4 + 1.4 + 2.3 + 1.1 + 1.9}{7}$$

$$= \frac{11.5}{7}$$

= 1.6 cm

Determine the maximum and minimum values of the seedling height.

Minimum value = 1.1; Maximum value = 2.3

Calculate which of these values is furthest from the mean.

1.6 – 1.1 = 0.5

2.3 – 1.6 = 0.6

Select the largest of these values to become the uncertainty.

Mean seedling growth = 1.6 ± 0.6 cm

1.2 Check your learning

Retrieve

1 **Define** the term 'uncertainty'.
2 **Define** the term 'accuracy'.

Comprehend

3 **Explain** why a measuring cylinder or burette should be used to measure a volume instead of a beaker.

Analyse

4 **Calculate** the volume and uncertainty of the volume shown in Figure 3.

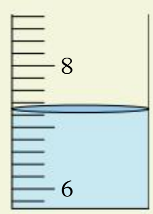


Figure 3 Water in a measuring cylinder

5 **Calculate** the value and uncertainty of the final volume when solution A (23.8 ± 0.2 mL) is added to solution B (13.2 ± 0.2 mL).
6 **Calculate** the mean and uncertainty of the following values: 19.6, 12.9, 21.8, 11.2.

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

1.3 Scientists prepare Safety Data Sheets

Learning intentions

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

- describe the purpose of Safety Data Sheets and provide examples of some of the types of information included on them.

Key ideas

- A Safety Data Sheet (SDS) contains information about a chemical, such as its various names, the dangers involved in its use and the precautions that should be taken when handling the chemical.
- SDSs should be prepared for all the reactants used and the products produced during science experiments.

Figure 1 Pictograms such as these are often seen on the labels of chemicals, to communicate specific hazards.

Anticipate, recognise and eliminate

Scientists work with many hazardous materials when completing experiments. As a result, they need to be aware of anything that might affect their health or safety in the laboratory. The laboratory is a safe place, provided hazards are:

> anticipated
> recognised
> eliminated or controlled.

Safety Data Sheets

A Safety Data Sheet (SDS) provides scientists and emergency personnel with information on how to use a particular substance. An SDS also helps scientists understand more about how the chemical should be used during an experiment.

Figure 2 Emergency workers in sealed positive-pressure protective suits communicating with each other

Safety Data Sheets can contain a lot of information, some of which is demonstrated in the example provided in Figure 4. An SDS can also include:

> **How to dispose of the chemical safely.** This section should include what disposal containers should be used, the effects of sewage disposal and the special precautions that may be needed to ensure the safety of individuals and the environment.
> **How to transport the chemical.** Information should include any special precautions for transporting this chemical. This may include the Hazchem code (the code provided by the government for each class of chemical).
> **An Australian telephone number of the Office of Chemical Safety.**
> **The date the SDS was last reviewed.**

The hazards identified in the Safety Data Sheet are often used by industries to create safety signs which they display around the work environment.

Figure 3 The hazards identified in the SDSs are displayed by many industries, including the mining industry.

SAFETY DATA SHEET

Sodium Chloride: Hazardous chemical

Section 1 - Identification	
MSDS name:	Sodium Chloride
Synonyms:	Common salt; Halite; Rock salt; Saline; Salt; Sea salt; Table salt.
Company identification:	Chemical company
Section 2 - Hazard(s) identification	
Eye and skin:	May cause eye irritation.
Ingestion:	Ingestion of large amounts may cause gastrointestinal irritation. Ingestion of large amounts may cause nausea and vomiting, rigidity or convulsions.
Inhalation:	May cause respiratory tract irritation.
Section 3 - Composition and information on ingredients	
Physical state:	Solid
Appearance:	Colourless or white
Odour:	Odourless
Boiling point:	1413 deg C
Freezing/melting point:	801 deg C
Solubility:	Soluble
Specific gravity/density:	2.165
Molecular formula:	NaCl
Molecular weight:	58
Section 4 - First aid measures	
Eyes:	Flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical aid.
Skin:	Flush skin with plenty of soap and water for at least 15 minutes while removing contaminated clothing and shoes. Get medical aid if irritation develops or persists. Wash clothing before reuse.
Ingestion:	If victim is conscious and alert, give 2-4 cupsful water. Get medical aid. Wash mouth out with water.
Inhalation:	Remove from exposure to fresh air immediately. If breathing is difficult, give oxygen. Get medical aid if cough or other symptoms appear.
Section 5 - Fire-fighting measures	
General information:	Water runoff can cause environmental damage. Collect water used to fight fire. Wear appropriate protective clothing to prevent contact with skin and eyes. Wear a self-contained breathing apparatus (SCBA) to prevent contact with thermal decomposition products. Substance is noncombustible.
Section 6 - Accidental release measures	
Spills/leaks:	Vacuum or sweep up material and place into a suitable disposal container. Clean up spills immediately, observing precautions in the Protective Equipment section. Avoid generating dusty conditions. Provide ventilation.
Section 7 - Handling and storage	
Handling:	Use with adequate ventilation. Minimise dust generation and accumulation. Avoid contact with eyes, skin, and clothing. Keep container tightly closed. Store in a cool, dry, well-ventilated area away from incompatible substances. Store protected from moisture.
Section 8 - Exposure controls and personal protection	
Engineering controls:	Good general ventilation should be used.
Personal protective equipment	
Eyes:	Wear safety glasses with side shields.
Skin:	Wear appropriate gloves to prevent skin exposure.
Clothing:	Wear appropriate protective clothing to minimise contact with skin.

The various names of the chemical
This includes its chemical name and its common generic name, its concentration and structure. For example, DL-threo-2-(methylamino)-1-phenylpropan-1-ol is also called pseudoephedrine.

Physical and chemical properties of the substance
Everyone in a laboratory should be able to easily identify the chemical. The SDS should include the colour, smell, pH, flammability, solubility, melting and boiling points of the chemical.

Fire-fighting measures
Some chemicals produce toxic fumes or are highly flammable. Other chemicals become more dangerous if they are exposed to water. Firefighters may need special equipment.

Usage instructions and restrictions
Some chemicals may form a dust that can explode. For example, workers in flour mills need to be especially aware of flour dust. This section provides information about how to safely handle and store the substance to minimise the risks.

Contact details of the manufacturer

Hazard level of the chemical
All chemicals should contain labels relating to their particular dangers. This may include flammability, corrosive ability, toxicity and ability to cause long-term damage, such as cancers. The risks can be shown using descriptions or the symbols shown in Figure 1.

What to do in the case of a spill
This includes first aid measures, any antidotes, symptoms that might result from exposure and if personal protective equipment (PPE) is recommended for the aiders. Advice may be needed on how to cover drains to prevent the chemical making its way into ground water.

Protective measures
Information on the eye and face protection needed, the type of gloves or skin protection required and the possible need for masks.

Figure 4 Example of an SDS from a manufacturer or certified provider

1.3 Check your learning

Retrieve

1 **Define** the term 'SDS'.

Comprehend

2 **Explain** why it is important to review SDSs before starting an experiment.

3 **Explain** why it is important to have all the different names of a chemical on its SDS.

4 **Describe** the types of personal protective equipment (PPE) you have in your laboratory.

Analyse

5 Find an SDS for one of the chemicals used in Challenge 2.11. **Identify** the different sections in the SDS. **Compare** your list to your neighbour's list.

Apply

6 **Determine** the name and contact details of the government body in your state that regulates chemicals.

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

1.4 Scientific data must be validated

Learning intentions

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

- describe factors that affect the validity of an experiment
- identify the validity of secondary sources
- explain why extrapolating data can introduce errors.

Key ideas

- A valid experiment tests the scientific question being asked.
- Scientists justify their claims (using multiple sources of evidence).
- Scientists must be ethical.

Valid experiments

Many manufacturers make strong claims that their product is better or improves everything from health and fitness to cleanliness. These companies may also show data that they say supports their claims, but it is always worth looking at the way the experiment was done to check if it was a valid test. Valid experiments will measure data directly related to the scientific question and hypothesis.

Things to consider include:

> Are all the variables controlled?
> Are there any errors in measurement?
> Were the correct instruments used to measure relevant data?
> Is there any other plausible explanation for the results?
> Were the data manipulated to fit expectations?

An example of a poorly designed experiment is one based on the scientific question 'Does chocolate cause weight gain?'. The researchers compared the weight and diets of two groups of people. They found that everyone had different diets, but the people in the healthy weight group ate more chocolate than the people in the overweight group. The researchers could have concluded that chocolate made people lose weight, but they knew that the experimental comparison was not valid because there were too many uncontrolled variables. This meant that there were many other factors (overall diet or exercise) that could have contributed to the results. The experiment also assumes that weight is a measure of a lack of health. A person who does a lot of exercise or who builds up muscle mass may be heavy but will also have low body fat. This means the experimental comparison fails the valid test for both method and measurement.

Validity of secondary sources

Social media is full of big claims and headlines quoting the latest scientific claim. These claims cannot be trusted unless they pass the validity and credibility tests. There are a number of things to look for before the claim is even read.

Who is the author?

It is always worth checking who wrote the article before reading their claims. Is the author qualified in that field? During the COVID-19 pandemic, there were many 'doctors' claiming to know about vaccines and the spread of viruses, but many of these people were not qualified in infection, epidemiology or even medicine. It is always worth asking, 'What are the author's qualifications?'

Why was the article written?

Some big headlines are written by companies that are wanting you to buy their product. Cosmetic companies will make claims that their skin cream will make you look younger, while car companies will claim that their oil will make your car run more smoothly. They will write an article or claim that will quote scientific data that make their product look the best and will often ignore data that disagree with their claim. Always consider why the article was written and if it is biased to a particular view.

Is it current?

A current claim does not just mean the most recently written article. While the date on the article of claim is important, it is worth checking if the data match other available data.

Figure 1 a Peer-reviewed articles in science journals are a valid secondary source because they have been checked by other scientists. **b** Posts and articles on social media are not always a valid source because they have not been checked for credibility and posts can often be sponsored by companies with their own agendas.

It is easy for a group of non-scientists to write an article each week with a new claim, but it is important to check if the data are able to be reproduced by other scientists. Does it fit with current research, or is it from the same group of people using the single set of data?

Is the publisher reputable?

Social media has a wide mix of trustworthy as well as untrustworthy publishers. This also happens with some online 'scientific' journals. There are some websites that claim to be scientific journals, but they are 'pay to publish' sites. These websites will publish any article that is written as long as the authors pay the company. In 2005, MIT students used a computer to generate random science and jargon words in a science paper. They then submitted the paper to a variety of science sites around the world. Some sites published the fake science paper. A good publisher will always peer review a paper before publishing. This means that the paper will be checked by other scientists who have been trained in the area.

Extrapolating graphs

Graphs can be used to show data that has been collected, but it can also be used to analyse the data and to make a conclusion.

When drawing a graph, it is important to:

> label each axis (with units)
> scale the axis so that it uses the space available
> consider if the line should pass through the origin (0,0)
> plot the graph and draw the line of best fit
> identify and explain any outliers.

Extrapolation occurs when data are estimated outside the known values. Extrapolating a graph occurs when a line is drawn for the estimated values. This can introduce an error to the data, because there is no data collected to support the conclusions that have been made (Figure 2).

extrapolation
estimating unknown values from trends in known data

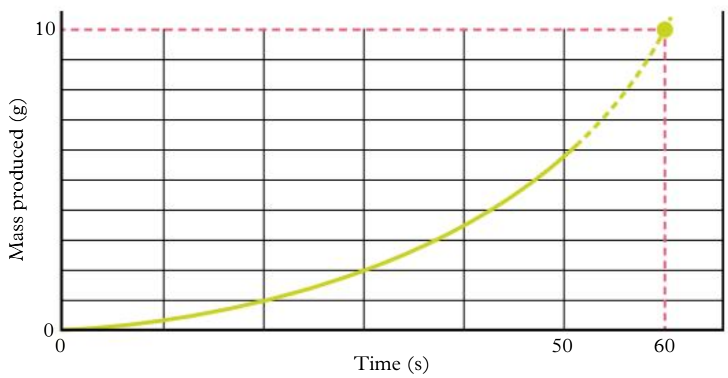


Figure 2 The data were only collected for 50 seconds. Extrapolating the data to 60 seconds can introduce errors.

1.4 Check your learning

Comprehend

1 **Describe** the factors that contribute to the validity of an experiment.

2 **Describe** what is meant by the phrase 'pay to publish'.

3 **Explain** why extrapolating a graph can lead to errors.

Analyse

4 **Contrast** what is meant by the terms, 'current' and 'recent' in scientific publishing.

5 **Identify** a source of secondary data from your social media. **Judge** the validity of the claim made in the information using the methods described.

Apply

6 **Identify** which of the following doctors below could be trusted to comment on vaccines. **Justify** your decision (by describing the qualifications of each type of doctor and comparing these to the type of information needed on vaccines).

> PhD of English literature
> veterinarian
> epidemiologist

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

//SCIENCE AS A HUMAN ENDEAVOUR//

1.5 Scientists investigate consumer products

Learning intentions

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

- describe the factors involved in designing a valid experiment and explain how to increase the reliability of results
- provide examples of common errors that should be minimised or avoided
- present data in an appropriate manner.

Working in groups of two or three, design an experiment to investigate an everyday consumer product. Your aim is to practise using the scientific method.

Use the 'Test your skills and capabilities' questions on the next page to design an experiment that investigates consumer products.

Figure 1 Investigating a consumer product: nail polish

Figure 2 More consumer products to investigate: bottled water and bubblegum

Figure 3 Scientists can identify the similiarites and differences between products or substances.

1.5 Test your skills and capabilities

Investigating a product

Choose a consumer product to **investigate** and **discuss** what you already know about the product. **Identify** any claims or slogans that may be tested. Then **design** a reproducible experiment to investigate these claims or slogans, following the scientific method.

You will need to research the product thoroughly. This may mean visiting a supermarket and comparing the prices and packaging of different brands, as well as searching the internet, journals, books and encyclopedias to identify the science behind your product.

Ideas

Here are some ideas for your investigation.

- Do all brands of bubblegum make the same-sized bubble?
- Do all washing detergents produce the same amount of bubbles and clean the same number of dishes?
- How permanent are permanent markers? What solvents (for example, water, alcohol, vinegar, detergent solution) will remove the ink? Do different brands or types of markers produce the same result?
- Do consumers prefer bleached white paper products or unbleached paper products? Why?
- Is laundry detergent as effective if you use less than the recommended amount? What if you use more than the recommended amount?
- Is bottled water more pure than tap water? How does distilled water compare with drinking water?
- How does the pH of juice change with time? How does temperature affect the rate of this chemical change?
- Do all hairsprays hold equally well? And equally long? Does the type of hair affect the results?
- Do all nail polishes dry at the same rate?
- Do some lipsticks stay on longer?
- How absorbent are nappies?
- Do all batteries have the same battery life?
- How long can the life of cut flowers be prolonged?

Evaluate

As a class, discuss each experiment design by answering the following questions.

- Will the experiment produce data that answer the question? (Is it valid?)
- Is the method repeatable? (Will the same process produce the same results if it is repeated?)
- Could someone else reproduce the results of the experiment under different conditions? (Are there any steps that require more scientific information to be supplied?)
- Have all the safety considerations been taken into account?
- What changes could be made to improve the design?

Planning for errors

Before you carry out your consumer science investigation, you will need to think about reducing errors and improving accuracy.

- What variables will you need to control to ensure a fair test?
- How will you make sure that your data are accurate and free of errors?
- What type of equipment will you be using? Is this the most appropriate equipment?
- How will you reduce parallax, reading and zero errors in your data measurements?
- What other factors could introduce errors into your investigation? How will you minimise these?

Presenting your results

Once you have completed your consumer science investigation, you will need to analyse your data appropriately.

- Are there any outliers? Can you explain these?
- What methods of data presentation will you use and why?
- What method will you use to describe your results: mean, median or mode?
- Are there any correlations between the sets of data in your results? Do they imply causation?

You will also need to complete a presentation about your investigation. This could be done as a webpage, a slide presentation, an advertisement, a video, or an article for *Choice* magazine, comparing your findings with the manufacturer's claims. Present your findings to the class.

1.6 Cognitive verbs identify the tasks in a question

Learning intentions

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

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

Key ideas

- Cognitive verbs are instructive words that require specific types of mental processes to perform set tasks.
- Cognitive verbs can be grouped into categories based on the level of cognition required to perform the task.

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

cognition
mental processes that are involved in acquiring, storing, manipulating and retrieving information

Cognitive verbs

Cognitive verbs are instructive words that require specific types of mental processing or '**cognition**' to perform set tasks. For example, the word 'explain' is a cognitive verb because it requires you to first recall what you understand about something and then reframe that understanding into clearer succinct terms. Cognitive verbs are often used in questions which means you will encounter a variety of different cognitive verbs in school as you learn new information and undertake assessments.

Familiarising yourself with different cognitive verbs and the tasks and thinking processes behind them can help you determine how to best respond to a question. An understanding of cognitive verbs can be the difference between achieving partial or full marks on an important exam or assessment question. Common cognitive verbs and the task/s associated with them are given in Table 1.

Some cognitive verbs require multiple or more complex cognitive processes than others. For example, if you were asked to *name* the two fruits in Figure 2, you may instantly recall 'apple' and 'orange'. However, if you were asked to *compare* the two fruits, you would also need to consider the two fruits and identify at least one similarity and one difference between them. In this sense, 'compare' involves more cognitive processes than 'name'.

Table 1 shows four different categories of thinking processes that can be used to group cognitive verbs. These are: retrieve, comprehend, analyse, and apply. 'Retrieve' questions come before 'apply' questions. This is because retrieve questions ask you to perform a simpler cognitive task – remembering – than apply questions. An 'apply' question requires you not only to recall information but also to interpret that information and determine how it can be used in a specific situation. Performing questions in order of simpler cognitive processes to more complex cognitive processes can support the way you acquire and understand new information.

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

Figure 2 Two healthy fruits

Table 1 Common cognitive verbs and their tasks

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

1.6 Check your learning

Retrieve

1 **Define** the term 'cognitive verb'.

2 **Identify** the cognitive verb that requires you to 'use knowledge and understanding to recognise trends and draw conclusions from given information' and **identify** the category of thinking process this verb belongs to.

Comprehend

3 **Explain** in your own words what is required to correctly answer:

a a 'discuss' question

b a 'calculate' question

c a 'predict' question.

Analyse

4 **Compare** the terms categorise and classify.

Apply

5 After conducting an experiment on how temperature affects the plant growth of corn and beet plants, a student was asked to, 'Identify which plant would be more suitable to grow in a hot environment. Justify your answer.' Their response was, 'The corn would be more suitable to grow in a hot environment'. **Evaluate** whether the student has correctly answered the question.

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

CHAPTER 1 REVIEW

SCIENCE TOOLKIT

Retrieve

1 **Identify** the most appropriate definition of 'independent variable'.
 A the variable that is measured
 B the variable that is controlled
 C the variable that is deliberately changed by the scientist
 D the variable that is measured at the end of the experiment

2 **Identify** which of the following statements is correct.
 A Correlation means causation.
 B Data are described in the method section of a scientific report.
 C Data are analysed in the results section of a scientific report.
 D A Safety Data Sheet should include the PPE to be used for a chemical.

3 **Identify** which of the following scientists could be trusted to make a claim on the growth rate of plants.
 A general practitioner in medicine (GP)
 B chiropractor
 C masters of Botany
 D PhD in epidemiology

4 **Identify** the main steps used when conducting an experimental investigation by the scientific method.

5 **Define** the term 'variable'.

6 **Identify** why consumer scientists are interested in what can be observed and tested, rather than in the slogans and claims of manufacturers.

7 A student conducts an experiment where they measure the amount of mass produced over time. They collect data for up to 50 seconds and then create the graph in Figure 1. **Recall** the term that describes what they have done with their graph.

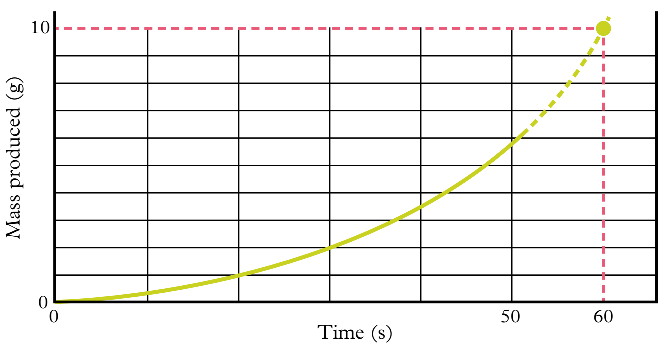


Figure 1 A graph created by a student

8 **Identify** three types of information that should be included on a Safety Data Sheet (SDS).

9 **Identify** the most accurate way to measure each of the following in your school science laboratory.
 a time
 b mass
 c length

10 **Define** the following terms.
 a valid
 b reproducible
 c accuracy

Comprehend

11 **Describe** how scientists find out about the safety risks involved in an experiment they are planning.

12 Suppose you are conducting a fair experiment in which you have identified six variables. **Explain** how you can be sure of the effect of one particular variable.

13 **Explain** why beakers are not used to measure volumes.

14 **Explain** why every experiment should have a large sample size.

15 **Explain** why it is important that scientific papers are peer reviewed.

Analyse

16 **Define** and **contrast** independent, controlled and dependent variables.

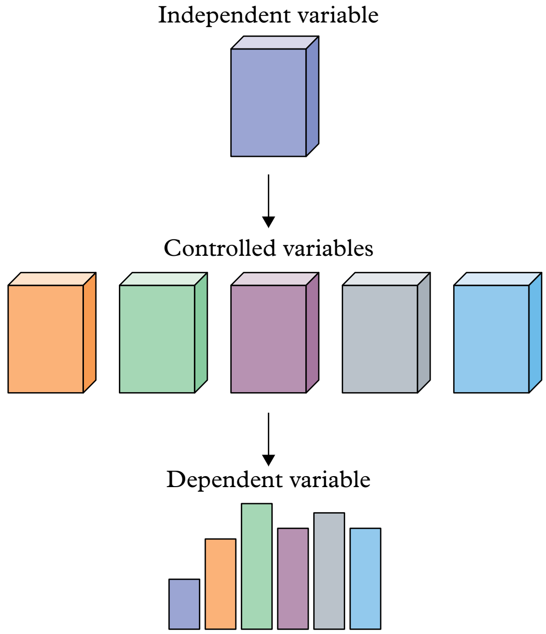


Figure 2 Variables

17 **Contrast** the four categories of cognitive verbs and **identify** an example of a cognitive verb and its task for each.

18 A student has written a report using information they read in an article posted on social media by an influencer. **Consider** whether the student has used a valid secondary source.

19 **Calculate** the mean and uncertainty of the following measurements.
18 mL, 15 mL, 21 mL, 14 mL, 14 mL, 19 mL

20 A student used a measuring cylinder to measure two volumes of 15 mL and 18 mL. The uncertainty for both measurements was 0.2 mL. **Calculate** the final volume and uncertainty if the two liquids were combined.

Apply

21 A consumer scientist wanted to test the effect of a lotion for treating acne. They first tested the lotion on a group of 20 teenagers, all aged 15, but then they decided to conduct more tests. So they then tested 100 more teenagers, all aged 15.

- a **Determine** whether this is an example of experimental repetition or increasing the sample size.
- b **Decide** which result (using 20 teenagers or 120 teenagers) is likely to lead to the most reliable conclusion. **Justify** your answer (by comparing the reliability of the test with 20 teenagers to that of 120 teenagers and deciding which is more reliable).

22 A scientist was commissioned by a jeans manufacturer to test various denims. The manufacturer wanted a more durable fabric than the one they were currently using. **Describe** how the scientist might test a fabric for durability in a valid way. **Discuss** why this is important.

Figure 3 How might a scientist test the durability of different denims?

23 A make-up manufacturer claims that their brand of tinted lip gloss will stay on for at least 6 hours, even during eating and drinking. **Create** an experiment based on the scientific method to test this claim. First **state** your hypothesis, and then **identify** the variables you will be considering. **Describe** the measurements you will take and how you will ensure that they are accurate.

24 For the experiment you designed in question 23, **predict** the results you would expect to obtain if your stated hypothesis was correct.

Figure 4 What results would be expected for the hypothesis from question 23?

25 For the experiment you designed in question 23, **evaluate** the accuracy of the results that you may measure and suggest what further investigation you could undertake to improve the reliability of your conclusions.

26 For the experiment you designed in question 23, assuming you found that the manufacturer's claim was correct, **create** a scientifically accurate slogan or advertisement for the lipstick based on your findings.

Social and ethical thinking

27 Two phrases commonly used in advertising are 'Scientists have proved …' and 'Recommended by scientists'. These are often accompanied by pictures of named scientists who are paid to appear in the advertisement. **Discuss** the ethical implications of using these phrases or pictures of scientists, by completing the following:

- a **Describe** why the company may choose to use the phrases or a picture of a scientist.
- b **Describe** how a person viewing the advertisement might be affected by the use of the phrases or pictures.
- c **Describe** how a person would be affected if the phrases/pictures were not used.
- d **Evaluate** whether using the phrases/pictures disadvantage the person viewing the advertisement.
- e **Decide** whether the phrases/pictures of scientists should be allowed in advertising.

Critical and creative thinking

28 One source of information for consumers is *Choice* magazine. The magazine reports the results of testing of a variety of brands of consumer products.

a If a consumer scientist was reading a report on the safety of children's pyjamas, **describe** the evidence they might look for to see if the report was fair and objective.

b If the scientist concludes that the report is reliable, **propose** how the public might be convinced to read the report before purchasing children's pyjamas.

Research

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

» Bottled water

Many people in Australia spend a lot of money on bottled drinking water. Are they doing this because of the way the water is marketed, or are there scientifically supported health benefits in drinking bottled water rather than tap water? Is tap water unsafe to drink? Have there been any cases where water bottlers have been fraudulent in their claims about the water they are selling? Investigate this issue.

- » Find out what dentists and medical experts say about bottled water.
- » Describe the scientific tests that are performed to check that the claims are correct and that the results that have been obtained are valid.
- » After researching and comparing a range of evidence, evaluate whether we should drink bottled water in Australia or use tap water.
- » Describe any limitations of your conclusions (for example, does it depend on where you live?).

Figure 5 Why do people drink bottled water?

» Mobile phone safety

Research is continuing into the safety of mobile phones, although most people in the Western world have one or use one. You are an advisor to the minister of communications and technology.

- » Produce a report, of at least 10 points, detailing any research that has taken place into mobile phone safety.
- » Make sure you assess the validity of these secondary sources.
- » Include the outcomes or conclusions reached in these studies.

Figure 6 People of all ages use mobile phones.

» Artificial colourings and flavourings in foods

Some people claim that certain artificial colourings and flavourings in foods can cause problems, such as hyperactivity in children. Use the internet and other resources to investigate this issue.

- » Describe the reliability of each of the sources that you use by identifying the source, the reason for the article, the validity of the data used.
- » Define the term 'opposing evidence'.
- » Identify whether the warnings are based on anecdotal evidence or scientific evidence.
- » Discuss whether anecdotal evidence can be of value to scientists.

Figure 7 Are artificial colourings and flavourings in foods bad for us?

Chapter checklist

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

	I can do this.	I cannot do this yet.
• Explain the differences between variables, the independent variable and the dependent variable, in terms of what is controlled, changed or measured. • Describe how sample size and repetition affects the reliability of a test. • Write a scientific report with all relevant sections.	☐	☐ Go back to Topic 1.1 'Scientists can test manufacturers' claims'. Page 4
• Define accuracy and uncertainty. • Identify the correct equipment to use to get an accurate measurement. • Describe how experimental errors can affect the outcome of an experiment.	☐	☐ Go back to Topic 1.2 'Scientists must be aware of experimental errors'. Page 8
• Describe the purpose of Safety Data Sheets and provide examples of some of the types of information included on them.	☐	☐ Go back to Topic 1.3 'Scientists prepare Safety Data Sheets'. Page 10
• Describe factors that affect the validity of an experiment. • Identify the validity of secondary sources. • Explain why extrapolating data can introduce errors.	☐	☐ Go back to Topic 1.4 'Scientific data must be validated'. Page 12
• Describe the factors involved in designing a valid experiment and explain how to increase the reliability of results. • Provide examples of common errors that should be minimised or avoided. • Present data in an appropriate manner.	☐	☐ Go back to Topic 1.5 'Science as a human endeavour: Scientists investigate consumer products'. Page 14
• Recognise the cognitive verb in a question. • Understand the different tasks involved for different cognitive verbs.	☐	☐ Go back to Topic 1.6 'Cognitive verbs identify the tasks in a question'. Page 16

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

Quizlet
Play a Quizlet game to test your knowledge.

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

CHAPTER

2

CONTROL AND REGULATION

2.1

Receptors detect stimuli

> Identify the five senses and the receptors associated with each type of stimulus.
> Describe how the structure of the sense organs is related to the type of stimulus they receive.

2.2

Nerve cells are called neurons

> Describe the passage of information through a neuron, across the synapse and to the next cell.
> Explain how sensory, motor and interneurons communicate information around the body.

2.3

The nervous system controls reflexes

> Describe the stimulus–response model.
> Explain how reflex actions can provide responses that save lives.

2.4

The central nervous system controls our body

> Describe the roles of the central nervous system, peripheral nervous system, somatic nervous system and autonomic nervous system.
> List the lobes of the brain and describe their main functions.

2.5

Sometimes things go wrong with the nervous system

- Provide examples of diseases and problems affecting the nervous system.
- Explain the relationship between the myelin sheath and multiple sclerosis.

2.6

The endocrine system causes long-lasting effects

- Describe the fight, flight or freeze response.

2.7

Homeostasis regulates through negative feedback

- Describe the advantage of homeostasis.
- Explain how hormones regulate blood glucose.

2.8

Sometimes things go wrong with homeostasis

- Explain what causes type 1 diabetes.
- Define and contrast hyperglycaemia and hypoglycaemia.
- Describe what occurs when somebody experiences hypothermia.

2.9

Science as a human endeavour: Hormones are used in sport

- Describe the function of erythropoietin and how athletes may use it to improve their performance in sporting events.

2.10

Science as a human endeavour: Pathogens cause disease

- Provide examples of pathogens.
- Describe the scientific discoveries that led to the development of the 'germ theory'.

2.11

The immune system protects our body in an organised way

- Describe some of the body's first-line defence mechanisms against infection.
- Compare naturally acquired immunity with vaccinations.

2.12

Sometimes things go wrong with the immune system

- Describe the immune response during an allergic reaction.
- Describe the common symptoms of rheumatoid arthritis and type 1 diabetes.
- Describe the cause of HIV and relate it to the development of AIDS.

What if?

Exploring your senses

What you need:

Blindfolds

What to do:

1. With a partner, explore how the senses of touch, hearing and smell can be used to navigate around a room without the use of sight.
2. Ensure all small or potentially hazardous obstacles are removed from around the room. Decide with your partner the path that the blindfolded student is required to take around the room.
3. Take turns being blindfolded and navigating the room, with your partner walking with you to ensure your safe navigation and providing assistance if needed.

What if?

» What if you wore earmuffs as well as the blindfold?
» What if you blocked your nose?
» What if you were barefoot?

2.1 Receptors detect stimuli

Key ideas

- Your body has receptors that detect changes (stimuli) in the environment.
- The five main types of external receptors detect light, sound, chemicals in the air and in your mouth, and touch.

Learning intentions

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

- identify the five senses and the receptors associated with each type of stimulus
- describe how the structure of the sense organs is related to the type of stimulus they receive.

Video 2.1
How taste works

Interactive 2.1
The human ear

stimulus
any information that the body receives that causes it to respond

receptor
a structure that detects a stimulus or change in the normal functioning of the body

Your body responds to changes in its environment. Receptors detect these changes and pass the information to other parts of the body. A stimulus is any information that your body receives that might cause it to respond.

Responding to change

Within our bodies, we regularly respond to changes without being aware of a **stimulus** and response. What makes you aware that you're hungry or thirsty? Something in your body is communicating with your brain to tell you to find food or water (Figure 1). A similar process occurs when you feel tired or have a headache. What is the source of these stimuli?

Other examples of stimuli are less obvious. We are surrounded by bacteria, viruses and fungi. Although many of them are too small to see, our bodies are constantly monitoring their numbers and fighting off harmful microorganisms (Figure 2).

Your body is an amazing combination of cells, tissues, organs and systems, all working together. Each plays a part in detecting stimuli and passing on the information to other parts of the body. The structures that detect stimuli or changes in the environment are called **receptors**.

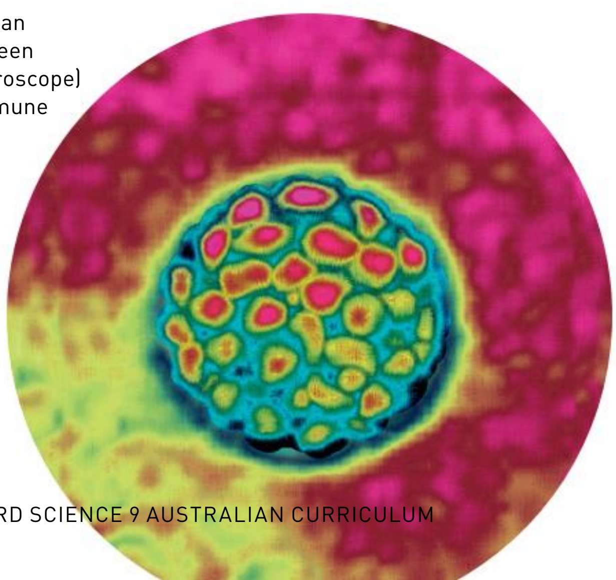


Figure 2 The human papillomavirus (seen here under a microscope) stimulates an immune response in the human body.

Figure 1 We often respond to hot weather by drinking more.

The sense organs

Our body can detect five main signals: light (sight), sound (hearing), chemicals in the air (smell) and in our mouth (taste), and touch. These are external senses because they tell us about the world outside our body. The sense organs – the eyes, ears, tongue, nose and skin – are highly specialised to receive stimuli from the environment.

Sight

Sight tells us more about the world than any other sense. The pupils change size to control how much light enters the eyes. The different types of photoreceptor cells at the back of the eyes transform the light into nerve signals for the brain (Figure 4).

CHALLENGE

2.1: Testing your senses
Go to page **179**.

Figure 3 A crocodile's eye has an elliptical (oval-shaped) pupil, which helps to protect its sensitive retina from the bright light of day.

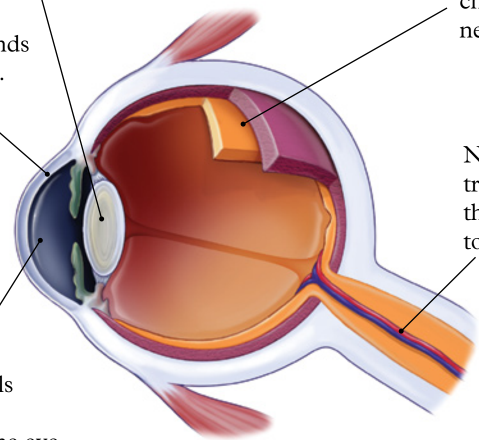


Figure 4 Photoreceptors in the human eye transform light into nerve signals.

It is not only your eyes that allow you to see, but also your brain! The information from your eyes is transferred to your brain, which then tells you what you are seeing.

Hearing

The strumming of a guitar causes the particles in the air to vibrate. This in turn causes your eardrums to vibrate. The vibrations are transferred along the bones of the middle ear – the smallest bones in your body – and into your cochlea to be converted into nerve impulses (Figure 6). The brain then interprets the information, telling you what you are hearing.

Figure 5 The large ears of some bats help them use sound waves to locate their prey.

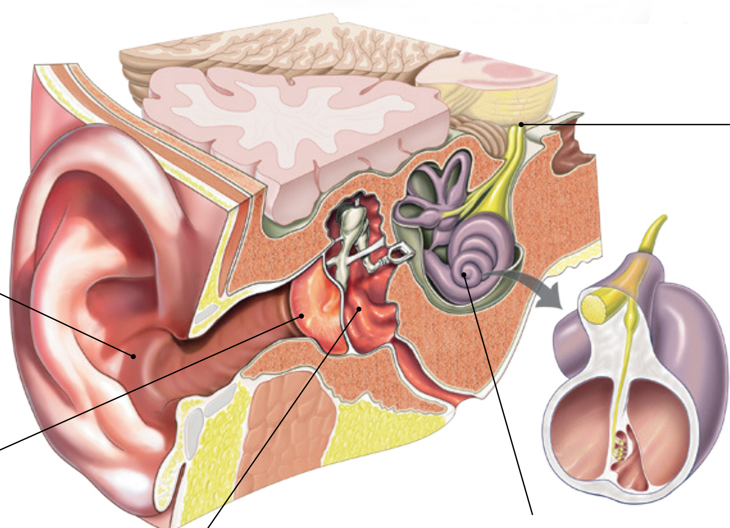


Figure 6 The human ear transfers vibrations to the middle ear. These vibrations become nerve impulses.

Figure 7 A dog uses its tongue for many things, including taste and temperature control. Panting moves cool air over the tongue and lungs, allowing moisture to evaporate, thus cooling the body.

Taste

Your tongue is covered in thousands of tiny taste buds (Figure 8). You can see this in a mirror. Taste buds contain special receptor cells that react to chemicals in foods. These chemical receptors can recognise basic kinds of taste molecules, such as sweet, salty, sour, bitter and umami (savoury). When you eat or drink, the information from the taste receptor cells is sent to your brain through nerves. It is the mix of chemical molecules that your brain detects as the flavours you are tasting.

Smell

Like taste, our perception of smell depends on chemical receptors. The receptors in our nostrils detect chemicals in the air and then send messages to the brain, which interprets the messages and tells us what we are smelling (Figure 10). Smell is closely linked to taste. If this seems strange, think about the last time you had a bad cold and a blocked nose. Did it affect your ability to taste? A lot of what people think is taste is actually smell.

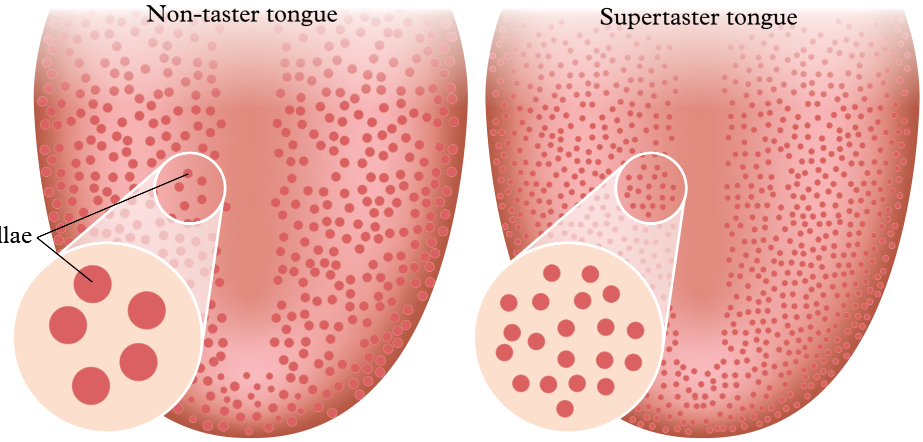


Figure 8 The tongue is covered in bumps, called papillae, which contain tastebuds that enable us to taste. A supertaster has many more papillae than average, and a non-taster has fewer.

Figure 9 Elephants use their trunks for a wide range of smelling tasks, such as sensing danger.

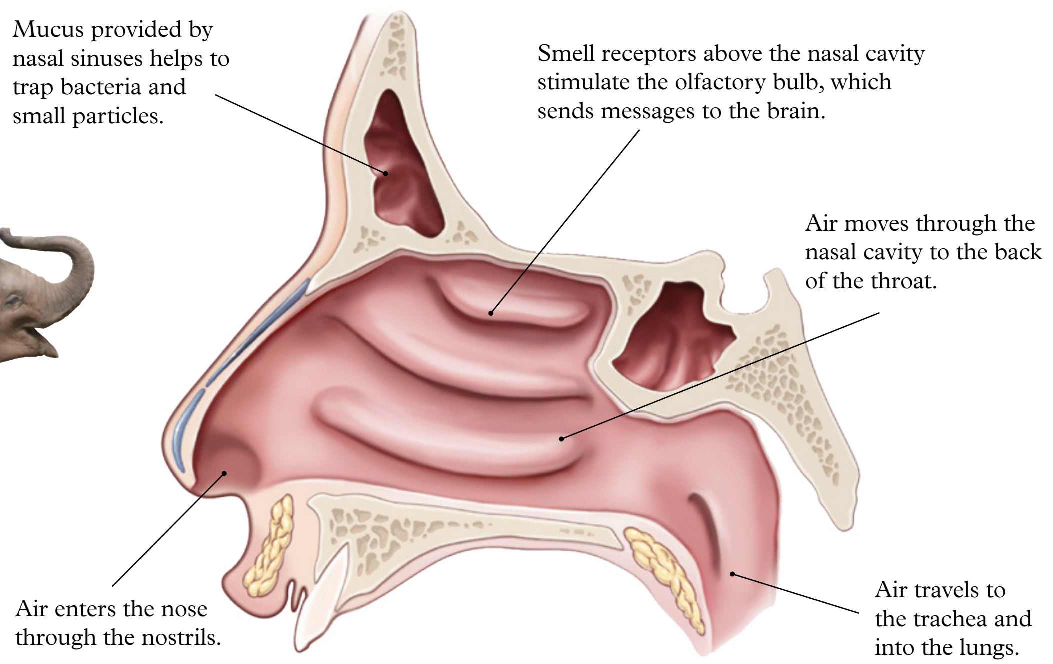


Figure 10 Smell receptors in human nostrils detect chemicals and send messages to the brain.

Touch

While the other four senses are in specific locations, touch is felt all over the body, through the skin (Figure 12). The inner layer of skin, called the dermis, contains many nerve endings that can detect heat, cold, pressure and pain. Information is collected by the different receptors and sent to the brain for processing and reaction.

Figure 11 The skin of a human fingertip has about 100 touch receptors.

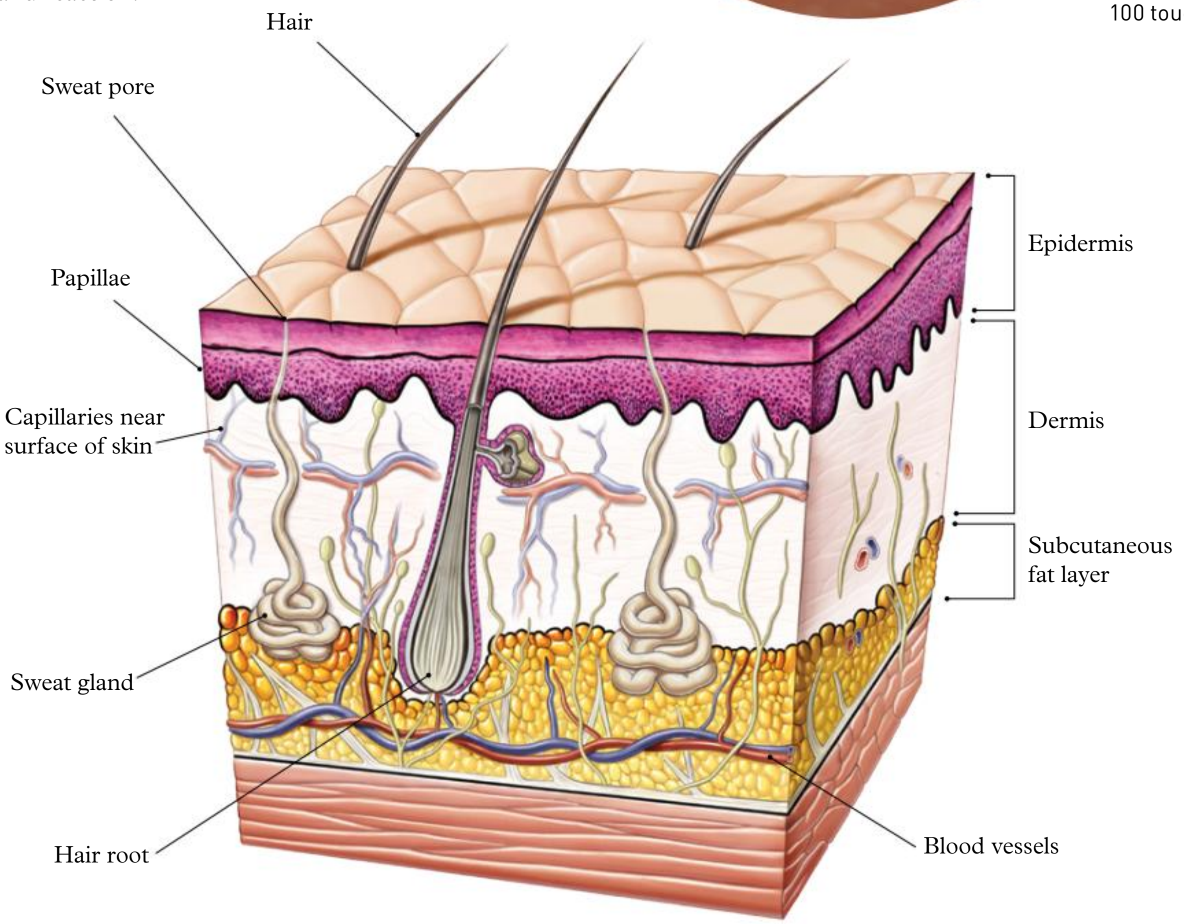


Figure 12 A cross-section of human skin

2.1 Check your learning

Retrieve

1 **Define** the term 'stimulus'.

2 **Identify** the five major sense organs.

Comprehend

3 Stimuli can be changes in our immediate environment or changes within our bodies. **Describe** two examples of each.

4 **Describe** two situations in which each sense organ would need to respond.

Analyse

5 **Compare** the way you detect smell and the way you detect taste.

Apply

6 'A person has more than five senses.' **Evaluate** this statement by:

> describing the five senses that are being referred to
> describing what happens to your balance when you spin around quickly (sense of balance)
> describing how your body reacts when you are sick (sensing bacteria)
> deciding whether the statement is correct.

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

2.2 Nerve cells are called neurons

Learning intentions

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

- describe the passage of information through a neuron, across the synapse and to the next cell
- explain how sensory, motor and interneurons communicate information around the body.

Key ideas

- Neurons are cells in our body that enable messages to be passed quickly.
- A change is detected by the receptor and an electrical message is passed along the neuron to the synaptic terminal.
- Chemical neurotransmitters pass the message across the gap to the next neuron.
- The myelin sheath protects parts of the neuron and increases the speed of messages being sent.

neuron
a nerve cell

cell body
the main part of a cell that contains the nucleus/genetic material

axon
the part of a neuron (nerve cell) that carries an electrical message away from the cell body to the synapse

myelin sheath
a fatty layer that covers the axon of a nerve cell

dendrite
the part of a neuron (nerve cell) that receives a message and sends it to the cell body

Nerves

The basic unit of the nervous system is the nerve cell, or **neuron**. Scientists believe that we may have up to 100 billion neurons in our bodies, connected in paths called nerves.

Neurons have many highly specialised features. Each neuron has a large **cell body** that connects to a long thin **axon** (Figure 1). An axon carries nerve impulses away from the cell body. The axons connecting your spinal cord to your foot can be up to 1 m long.

At the end of the axon are small bulbs, called synaptic terminals. Each synaptic terminal releases information into the synapse (Figure 2). The next neuron receives these messages from the synapse via its dendrites.

Nerves work just like electrical wires and require insulation in the same way. The axons are covered by a fatty layer called the **myelin sheath**. The myelin sheath helps to speed up a nerve impulse along an axon by controlling its path. People with multiple sclerosis have damaged myelin sheaths. This means that the nerve impulse is disrupted, blocked or unable to move along the length of the axon. A person with multiple sclerosis can therefore have difficulties with movement.

Dendrites are nerve endings that branch out of the cell body. These highly sensitive, thin branches receive information from the synaptic terminal of other neurons, allowing nerve impulses to be transmitted.

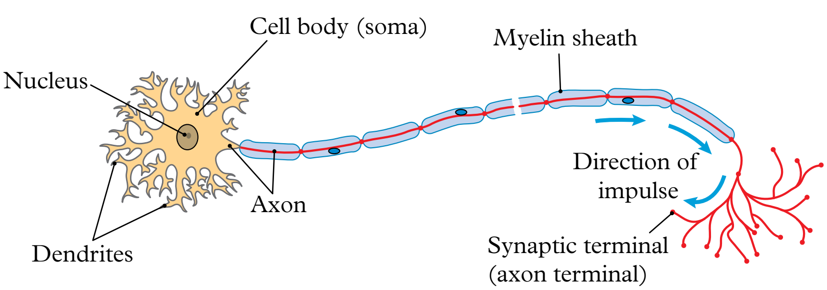


Figure 1 A typical neuron

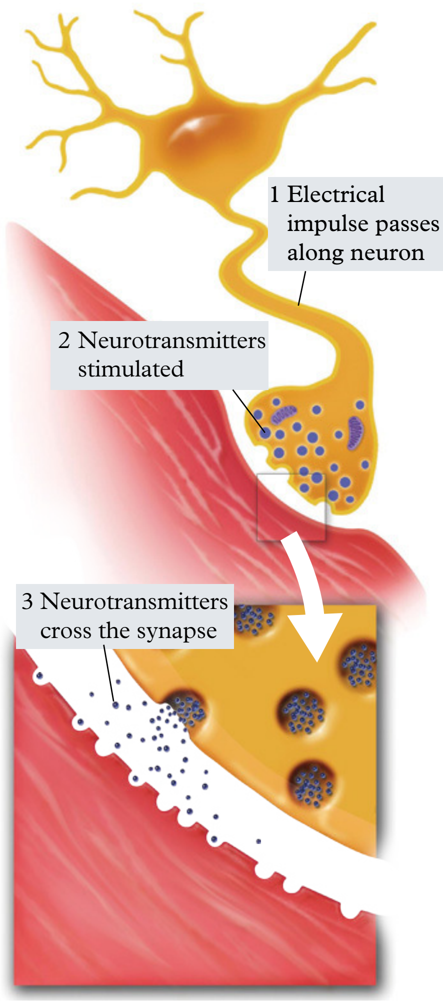


Figure 2 Electrical messages are converted to chemical messages (neurotransmitters), which cross the gap in the synapse.

CHALLENGE

2.2: Pipe cleaner neurons
Go to page 180.

Dendrites bring information to the cell body and axons take information away from the cell body. Information from one neuron flows to another neuron across a **synapse**. The synapse is a small gap separating neurons. When the message reaches the end of the axon, chemicals called **neurotransmitters** are released from the synaptic terminal and travel across the gap in the synapse to the dendrite of the next neuron. In this way, electrical messages are passed around the body.

There are three specialised types of neuron, all with different jobs.

> **Sensory neurons** (or afferent neurons) are sensitive to various stimuli, collecting information from either the body's internal environment or the outside world. Sensory neurons send the information they have collected to the central nervous system for processing.

> **Interneurons** (or connector neurons) link sensory and motor neurons, as well as other interneurons. Interneurons are the most common neuron in your central nervous system (brain and spinal cord). They only make connections with other neurons.

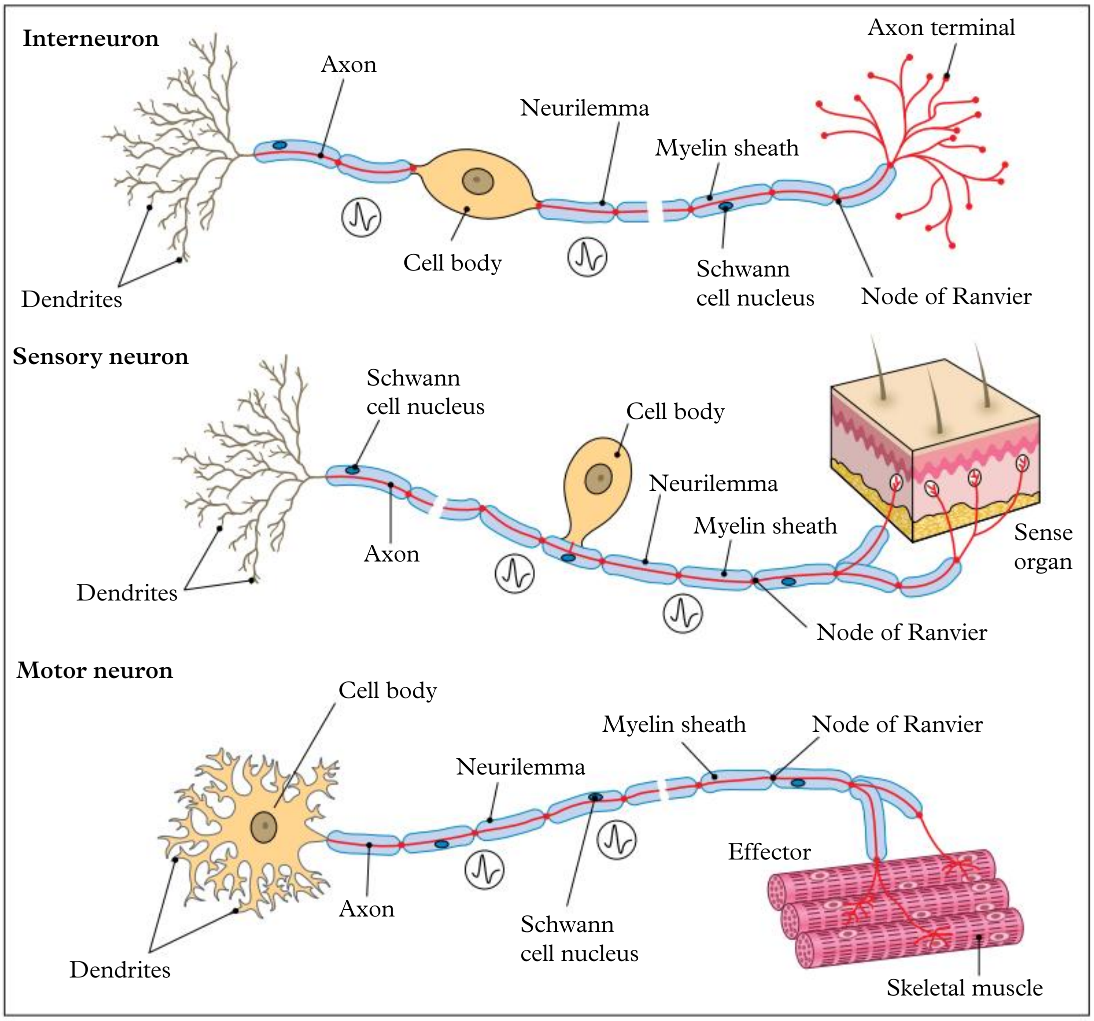


Figure 3 In these examples of an interneuron, a sensory neuron and a motor neuron, you can see how they are structured differently to send and receive different messages.

> **Motor neurons** (or efferent neurons) carry messages from the central nervous system to muscle cells throughout the body, which then carry out the response.

synapse
a small gap between two neurons that must be crossed by neurotransmitters

neurotransmitter
a chemical messenger that crosses the synapse between the axon of one neuron and the dendrite of another neuron

sensory neuron
a nerve cell that carries a message from a receptor to the central nervous system

interneuron
a nerve cell that links sensory and motor neurons; also known as a connector neuron

motor neuron
a nerve cell that carries a message from the central nervous system to a muscle cell

2.2 Check your learning

Comprehend

1 **Describe** the features of a neuron that enable it to pass messages on to other neurons.

2 **Describe** where you will find sensory neurons that detect:

a smell
b taste
c sound
d touch
e light.

3 **Describe** the role of the myelin sheath.

Analyse

4 **Compare** sensory neurons and motor neurons.

5 **Contrast** sensory neurons and interneurons.

Apply

6 With a partner, **create** a way to remember the difference between sensory neurons, motor neurons and interneurons. Be creative! Share your memory trick with the class.

7 **Create** a diagram to **explain** the problem that may result from damage to the myelin sheath.

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

2.3 The nervous system controls reflexes

Learning intentions

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

- describe the stimulus–response model
- explain how reflex actions can provide responses that save lives.

Video 2.3
Microscope skills

reflex
an involuntary movement in response to a stimulus

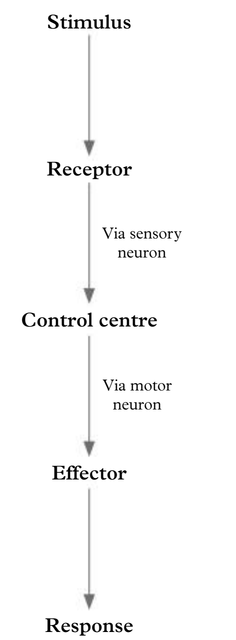


Figure 1 The stimulus–response model

Key ideas

- Receptors in the nervous system detect a stimulus and pass it on to control centres.
- The control centres initiate a message to the effectors, which causes a response.
- Reflexes are special pathways that allow a response to occur before the brain has time to think.

Stimulus–response model

Stimuli can come in many different forms. A stimulus may be pressure or heat on the skin, a puff of air or strong light in your eye. The stimulus is detected by receptors and the message gets sent to the spinal cord and the brain via sensory neurons. The spinal cord and brain are the control centre of the nervous system. Interneurons in this control centre pass the message on to other interneurons as your brain thinks about how you should respond to the stimulus. Eventually, you make a decision and the motor neurons pass the message on to the muscles. In this case, the muscles are called the effectors, because they are the cells that cause the body to respond. This simple pathway is called the stimulus–response model (Figure 1).

Reflexes

If you have ever accidentally touched something very hot, you will remember how quickly you snatched your hand away. In fact, it would have been so quick that you didn't even have time to think about it – it was automatic.

A **reflex**, or reflex action, is an involuntary and nearly instantaneous movement in response to a stimulus.

During a reflex action, the sensory neuron carries the message from the receptor to the spinal cord. The interneuron then sends two messages at the same time: one to the brain and the other to the muscles via the motor neuron (Figure 2). This means the muscle is moving at the same time as the brain gets the message (e.g. that the object is hot). This makes reflexes even faster than usual responses. Most reflexes help us in survival situations. Can you think of the advantages of these reflexes?

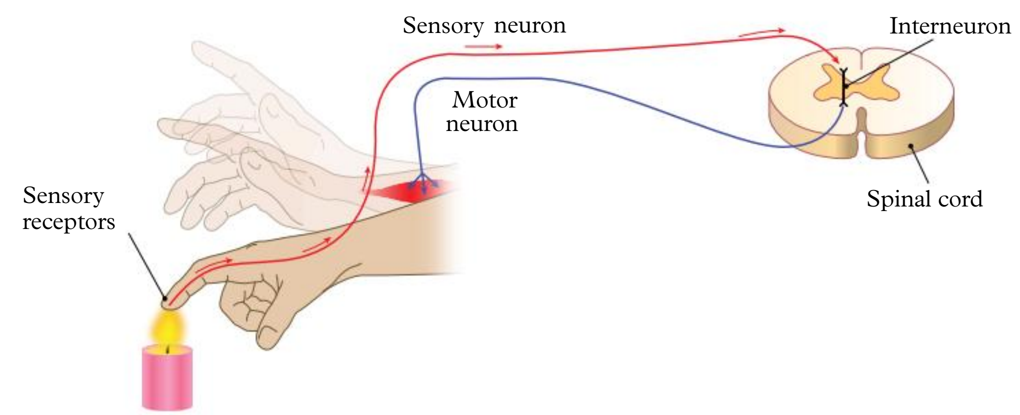


Figure 2 A reflex action ensures that your hand pulls away from the flame very quickly, even before you feel the pain.

CHALLENGE

2.3A: Testing reflexes
Go to page 181.

CHALLENGE

2.3B: How fast is the nervous system?
Go to page 182.

Figure 3 Grasp reflex When an object is placed on a baby's palm, their fingers curl over and grasp it.

Figure 4 Sneezing reflex When small particles land on receptors in the back of your nose, the muscles in your diaphragm force air out rapidly.

Figure 5 Startle reflex When a newborn baby is startled, they will fling their arms out wide and grab anything they touch.

Figure 6 Plantar reflex When a blunt object (such as the blunt end of a pencil) is moved along the underside of the foot, the toes usually curl downwards.

Figure 7 Patellar (knee-jerk) reflex When a small section below the kneecap (the tendon that connects the muscle to the bone) is stimulated with a quick, firm tap, the foot will kick out.

Figure 8 Quick reflexes!

2.3 Check your learning

Retrieve

1 **Define** the following terms.
   a receptor
   b effector
   c response

Comprehend

2 **Describe** the stimulus–response model of regulation.

3 **Explain** why the brain is not involved in a reflex action.

4 **Explain** the advantage of a baby having the startle reflex.

Analyse

5 If a person has a damaged upper spinal cord, they may not be able to feel their toes. **Analyse** whether this will affect their knee-jerk reflex (by describing how a person 'feels' their toes, describing the role of the spinal cord in a knee-jerk reflex and determining whether damage to the upper spinal cord will affect the messaging in a knee-jerk reflex).

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

2.4 The central nervous system controls our body

Learning intentions

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

- describe the roles of the central nervous system, peripheral nervous system, somatic nervous system and autonomic nervous system
- list the lobes of the brain and describe their main functions.

Key ideas

- Humans are constantly receiving stimuli from their environment through the peripheral nervous system.
- Neurons use electrical messages that are passed along to neurons in the brain and spinal cord that make up your central nervous system.

Video 2.4
The core of the nervous system

central nervous system
the brain and spinal cord

Central nervous system

The **central nervous system** is the control centre of the body. All incoming messages from your environment and your responses to them are processed through your central nervous system. The two main parts of the central nervous system are the brain and the spinal cord.

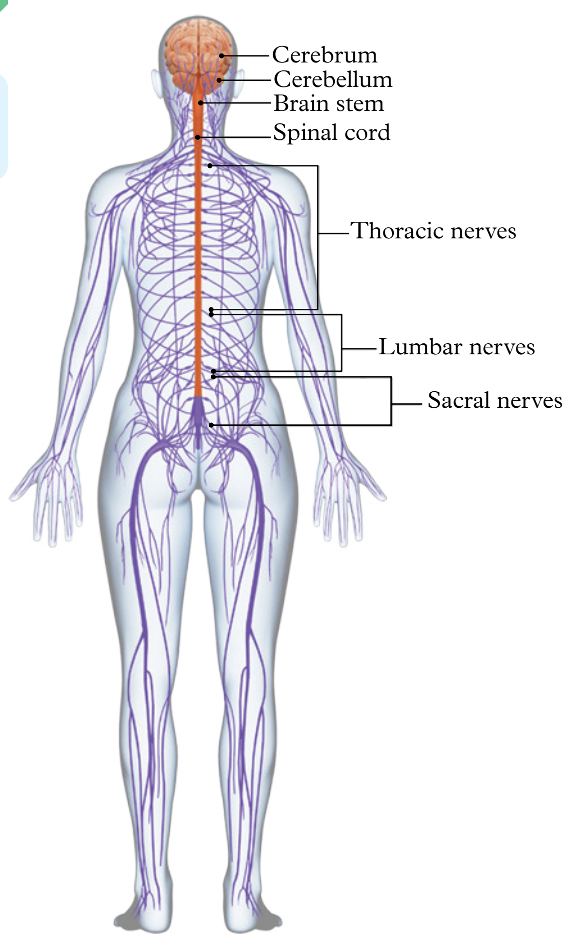


Figure 1 The nervous system of the body is made up of the central nervous system (red) and the peripheral nervous system (purple).

Brain

The brain is the processing centre of the body and is mainly concerned with your survival. It is a soft, heavy organ surrounded by a tough skull. The interneurons in the brain gather information about what is going on inside and outside the body. It then compares the information to events that have occurred previously, before making decisions about things such as internal changes and movements. The brain is also home to your memories, personality and thought processes.

Lobes of the brain

The cerebrum, or outer section of the brain, is divided into four lobes or sections. These lobes have specific functions (Figure 2).

- The frontal lobe is at the front of the brain. Its functions include emotions, reasoning, movement and problem solving.
- The parietal lobe manages the perception of senses, including taste, pain, pressure, temperature and touch.
- The temporal lobe is in the region near your ears. It deals with the recognition of sounds and smells.
- The occipital lobe is at the back of the brain. It receives all the information from your eyes. It is responsible for the various aspects of vision.

SKILLS LAB

2.4: Sheep brain dissection
Go to page **183**.

Peripheral nervous system

The **peripheral nervous system** is a large system made up of all the nerves outside the central nervous system. The peripheral nervous system carries information to and from the central nervous system to the rest of the body, such as the limbs and organs.

The peripheral nervous system is divided into two parts.

> The **somatic nervous system** controls voluntary skeletal muscle movements, such as waving or reaching out to take an object.

> The **autonomic nervous system** controls involuntary actions, which happen without our conscious control. This includes heartbeat, digestion, respiration, salivation and perspiration. The autonomic nervous system maintains your body's internal environment (homeostasis).

The autonomic nervous system also has two parts: the sympathetic division and the parasympathetic division. These two divisions often have opposite effects. For example, the parasympathetic division slows down the heart rate, whereas the sympathetic division speeds up the heart rate. The systems work together to maintain a balance in the body.

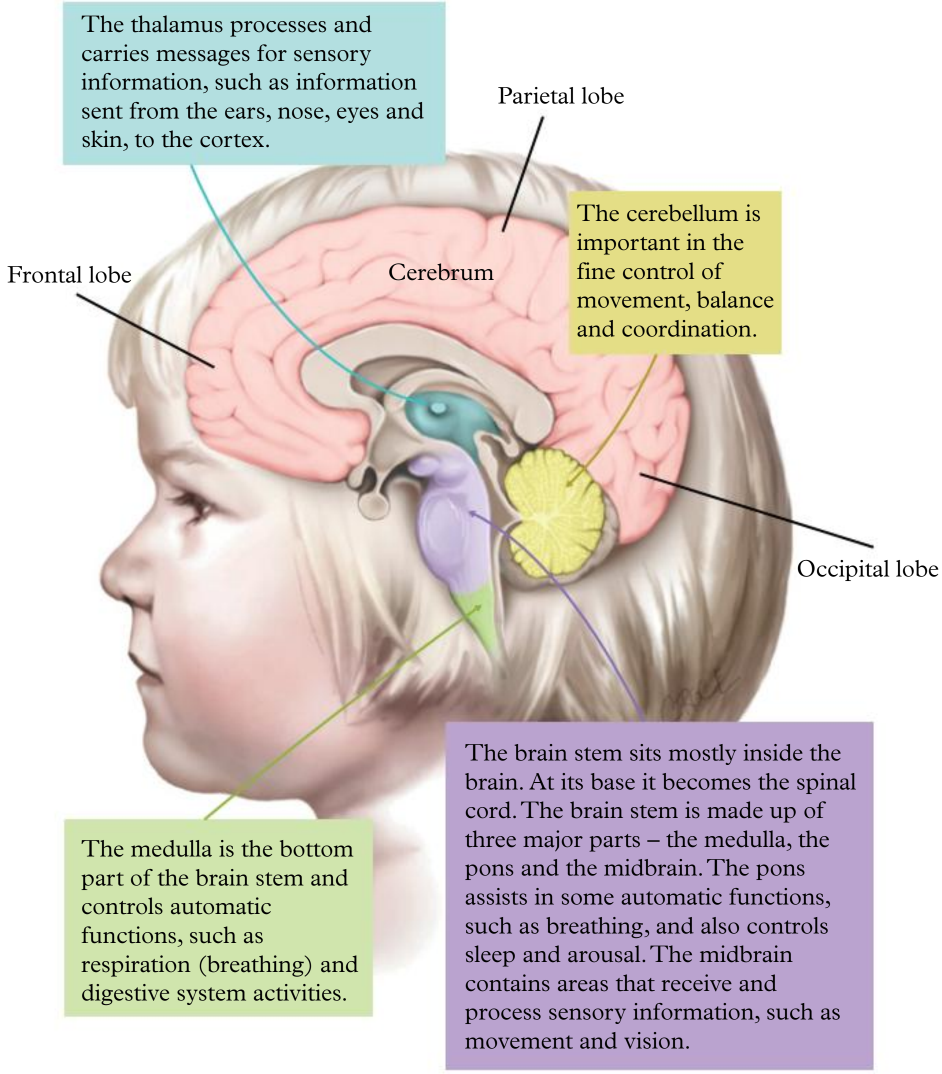


Figure 2 Structure of the human brain. The fourth lobe of the cerebrum, the temporal lobe (not shown here), is near the ears.

2.4 Check your learning

Retrieve

1 **Identify** the two parts of the body that make up the central nervous system.

Comprehend

2 **Describe** the role or function of the peripheral nervous system.

3 **Describe** how the peripheral nervous system and the central nervous system work together. Use an example to illustrate your answer.

4 **Explain** why, if you slipped and hit the back of your head, everything might go black.

5 **Describe** the possible effect on behaviour that would occur if a person had damage to the frontal lobe of their brain.

Analyse

6 **Contrast** the somatic nervous system and the autonomic nervous system.

Apply

7 **Create** a scientific diagram of the brain that shows the four lobes. In each of the lobes:

a write the functions that are carried out in that lobe

b draw something to remind you of the functions carried out in that lobe.

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

peripheral nervous system
all the neurons (nerve cells) that function outside the brain and spinal cord

somatic nervous system
the part of the nervous system that controls the muscles attached to the skeletal system

autonomic nervous system
the part of the nervous system that controls involuntary actions such as heartbeat, breathing and digestion

2.5 Sometimes things go wrong with the nervous system

Learning intentions

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

- provide examples of diseases and problems affecting the nervous system
- explain the relationship between the myelin sheath and multiple sclerosis.

Key ideas

- A slipped disc can press on the nerves in the spinal cord.
- When the myelin sheath is damaged in multiple sclerosis, the movement of the body can be affected.
- Motor neurone disease affects messages being passed to the muscles.
- Alzheimer's disease is caused by progressive damage to neuron functioning.

The nervous system plays a very important role in coordinating and regulating your body. Things that can go wrong with the nervous system include the spinal cord being damaged (paraplegia), things pressing on the nerves in the spinal cord (slipped disc), the myelin sheath in neurons being damaged (multiple sclerosis), the motor neurons failing (motor neurone disease) and damage to the neurons in the brain (Alzheimer's disease).

Spinal damage

Spinal injury is a major type of injury in Australia, especially in young men. These injuries commonly result from motor vehicle accidents, everyday falls and sports.

When the spinal cord is damaged, the messages from the neurons below the level of injury can no longer travel to the brain. This means the individual cannot receive messages from the sensors in this part of the body. It also means the messages from the brain cannot reach past the injury. How much of the body is able to move after a spinal injury depends on where the injury is in the spinal cord. If it is high up, most of the body is 'cut off' from the brain; if it is lower down, then the upper body and arms may be able to work as they normally would.

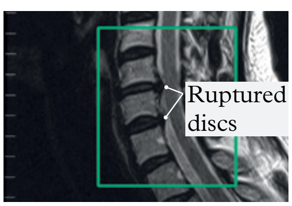
People with severe damage to the upper part of the spinal cord have quadriplegia – they are unable to use their arms or legs. If the injury is very high, they may even have trouble breathing on their own. People with severe damage below the arms have paraplegia – they are still able to use their arms but not their legs.

Slipped disc

Your backbone consists of 26 bones, or vertebrae, that surround the nerves of your spinal cord. Between each vertebra is a sac called a disc, which is filled with a thick fluid, or gel, and allows the vertebrae to move.

If a disc becomes weak and puts pressure on the nerves entering or leaving the spinal cord, this will cause pain or numbness along the nerve. Treatment usually involves pain relief, along with exercises that strengthen the muscles in the back. Occasionally, surgery is required to remove the damaged part of the disc.

a



b

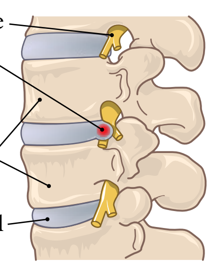


Figure 1 A slipped disc can put pressure on the spinal nerves. **a** X-ray of spine, showing two ruptured discs **b** A ruptured disc presses on the spinal nerve, causing pain.

Multiple sclerosis

The myelin sheath plays a very important role in ensuring the electrical message passes along the axon of a neuron.

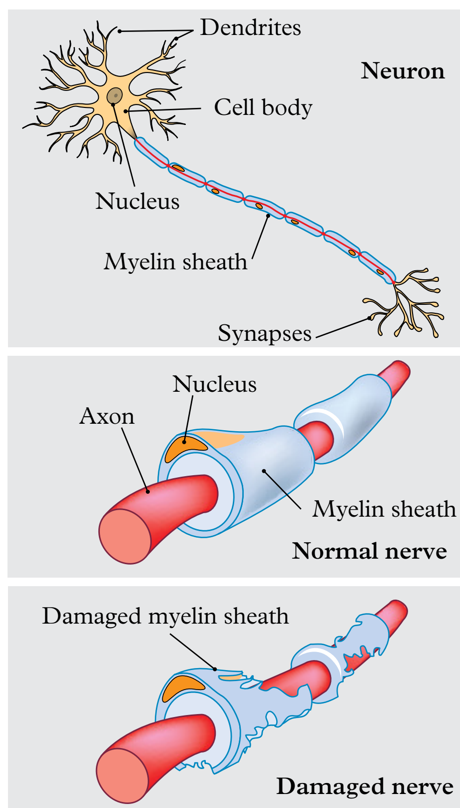


Figure 2 In multiple sclerosis, damage to the myelin sheath prevents the nerves from passing on messages.

If the myelin sheath is damaged, the electric signal can be lost, like a broken wire in an electric circuit. Your immune system usually fights and kills bacteria and viral infections. In multiple sclerosis, the immune system mistakenly recognises myelin sheath cells as dangerous, and attacks and destroys them. This means messages to and from the senses (including the eyes, skin and bladder) and the muscles become lost. Muscles can become weak, and the sufferer can feel dizzy or tired, or have difficulty seeing properly. Most commonly, the symptoms appear for a short time, before disappearing completely, and then returning later on. This is called a relapsing–remitting cycle.

Motor neurone disease

In motor neurone disease (also known as amyotrophic lateral sclerosis, ALS), the neurons that send messages to the muscles become weak and eventually lose function. As the muscles grow weaker, they can cramp and become stiff. This usually starts in the muscles in the legs and arms, before progressing to the face and chest. This can affect the person's ability to talk and, eventually, to breathe. Neurons in the brain are also affected by this disease. Scientists do not know what causes the motor neurons to lose function. Research in this area is continuing.

Alzheimer's disease

Alzheimer's disease is caused by progressive damage to the neurons in the brain. This gradually affects memory, and the ability to reason or plan and carry out everyday activities. Problems with short-term memory mean that the sufferer cannot remember what happened a few hours ago, or what they are meant to be doing that day. The disease also has wider impacts. Sufferers can forget where they are and how to get home. This makes life very confusing for them and they can become upset very easily. Symptoms can vary from day to day, depending on tiredness or stress. The cause of Alzheimer's disease is not known. Research suggests that plaques develop around neurons in the brain, making it hard for them to transmit messages. Chemical changes in the neurons may be caused by genetic, environmental and health factors.

Figure 3 AFL legend Neale Daniher was diagnosed with motor neurone disease (MND) in 2013. Daniher's diagnosis has increased awareness and fundraising for MND.

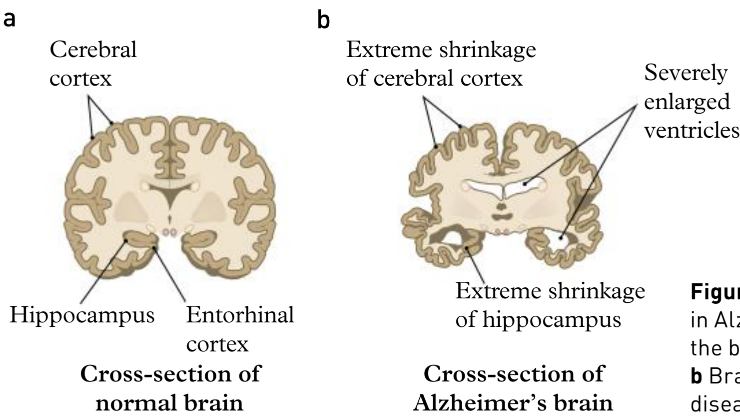


Figure 4 Damage to the neurons in Alzheimer's disease can cause the brain to shrink. **a** Normal brain **b** Brain of a person with Alzheimer's disease

2.5 Check your learning

Retrieve

1 **Recall** the name of the individual bones that make up the spine.

Comprehend

2 **Describe** the role of a disc in the spinal column.

3 **Explain** why the destruction of the myelin sheath causes symptoms in multiple sclerosis.

4 **Identify** another name for motor neurone disease. **Describe** the role motor neurons usually play in a healthy nervous system.

5 Think about where you were and what you were doing one hour ago. **Describe** how you would be affected if you could not remember this.

Analyse

6 **Contrast** quadriplegia and paraplegia.

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

2.6 The endocrine system causes long-lasting effects

Learning intentions

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

- describe the fight, flight or freeze response.

Key ideas

- The endocrine system uses chemical messengers called hormones to maintain control and to regulate growth.
- Hormones travel through the bloodstream to receptors or target cells.
- The effects of hormones often last longer than the effects of the nervous system.

Video 2.6
The endocrine system

endocrine system
a collection of glands that make and release hormones

hormone
a chemical messenger that travels through blood vessels to target cells

target cell
a cell that has a receptor that matches a specific hormone

The **endocrine system** is a collection of glands that secrete (release) **hormones**. The hormones are secreted directly into the bloodstream and then travel around the body through the blood. Some cells in the body have receptors that match the hormone, like a lock to a key. These cells are called **target cells**. It only takes one hormone 'key' to cause a change in the target cell 'lock'.

The glands and organs of the endocrine system are spread throughout the body (Table 1 and Figure 1).

Fight, flight or freeze?

If you are ever in a dangerous or frightening situation, you may experience a 'fight, flight or freeze' response. You break out in a cold sweat, your heart beats wildly, everything around you seems to slow down and your senses bombard you with information.

Most of these symptoms are triggered by the release of the hormone adrenalin (also called epinephrine). Adrenalin is constantly produced by the adrenal glands in small doses.

Table 1 Some organs and hormones of the endocrine system

Organ	Hormone	Target tissue	Main effects
Hypothalamus	Wide range of neurohormones	Pituitary gland	Sends messages from nervous system to the pituitary gland to control functions such as body temperature, hunger, thirst and sleep patterns
Ovaries	Progesterone	Uterus	Thickens wall of uterus to prepare for pregnancy
	Oestrogen	Body cells	Development of female sexual characteristics; aspects of pregnancy and foetal development
Testes	Testosterone	Male reproductive system, body cells	Development and control of male sexual characteristics; production of sperm
Pancreas	Insulin	Liver, most cells	Lowers blood glucose level
	Glucagon	Liver	Raises blood glucose level
Pituitary gland	Thyroid-stimulating hormone	Thyroid	Changes the rate of thyroxine release from the thyroid
	Antidiuretic hormone	Kidneys	Increases the amount of water reabsorbed from the kidneys
	Pituitary growth hormone	Bones, muscles	Stimulates muscle growth; controls the size of bones
Thyroid gland	Thyroxine	Body cells	Affects rate of metabolism, and physical and mental development
Parathyroid glands	Parathyroid hormone	Blood	Regulates the amount of calcium in the blood
Adrenal glands	Adrenalin	Body cells	Increases body metabolism in 'fight, flight or freeze' response
Pineal gland	Melatonin	Skin cells	Involved in daily biological rhythms

CHALLENGE
2.6: Glands and organs of the endocrine system
Go to page 184.

The adrenal glands are located above the kidneys. The usual function of adrenaline is to stimulate the heart rate and enlarge blood vessels. However, when you are in danger, the hormone takes on another role. It floods your system, causing an increase in the strength and rate of the heartbeat, raising your blood pressure and speeding up the conversion of glycogen into glucose, which provides energy to the muscles. In this way, adrenalin prepares your body for the extra effort required should you need to defend yourself (fight), run away (flight) or hide (freeze).

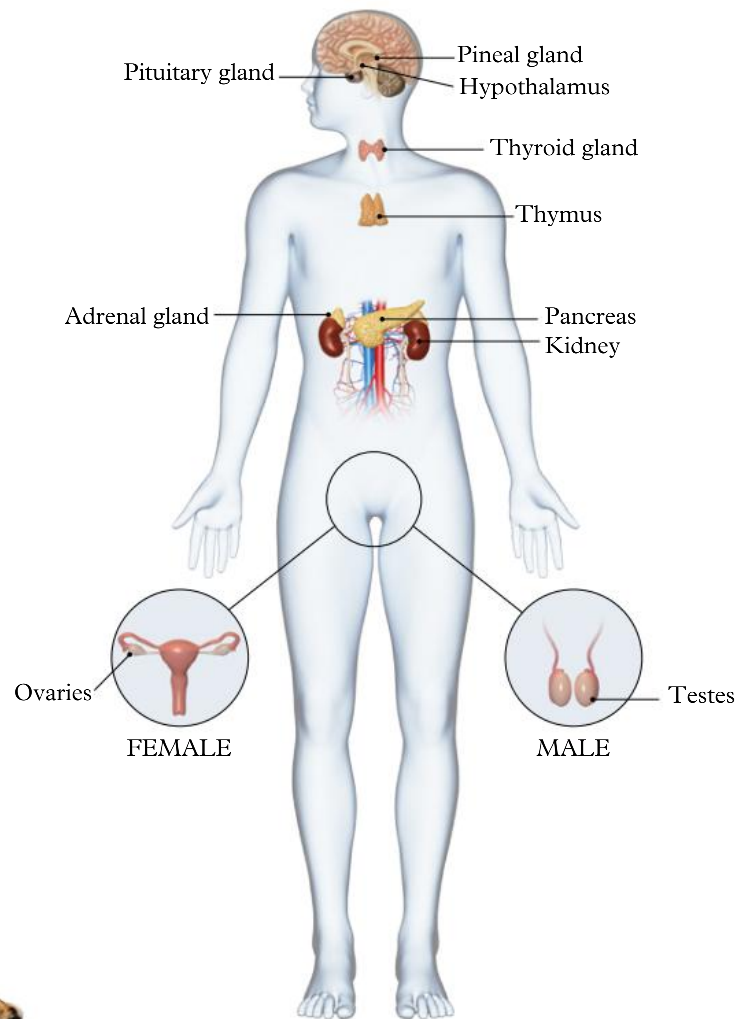


Figure 1 The human endocrine system

Panic attacks

Sometimes the 'fight, flight or freeze' response can be triggered without any obvious reason. This means adrenalin can flood the body, causing the heart to pound, breathing to become fast and shallow, and a flood of sensory information to stimulate the brain. When this occurs, lights appear brighter, sounds are louder and smells stronger. These sensory messages can become jumbled as the brain struggles to make sense of all the information. This combination of endocrine and nervous system responses is called a panic attack. These symptoms are not life threatening and will eventually disappear. Support from friends and family can help.

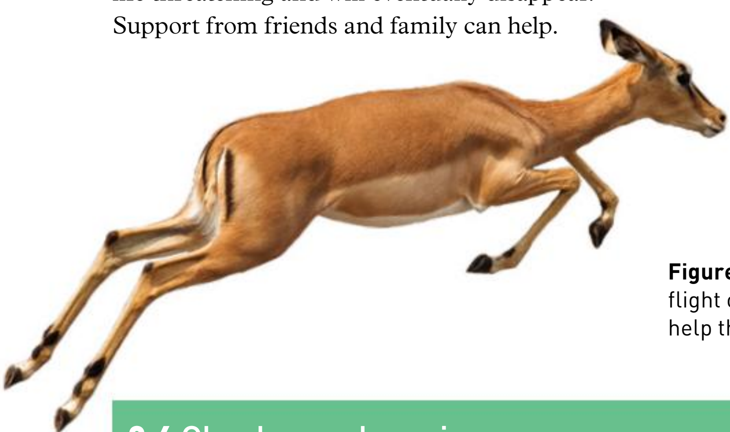


Figure 2 Adrenalin is responsible for the 'fight, flight or freeze' response in mammals and can help them to survive.

2.6 Check your learning

Retrieve

1 **Name** the system in your body that is responsible for hormones.

Comprehend

2 **Describe** what is meant by the phrase 'fight, flight or freeze' and how it relates to hormones.

3 **Describe** the symptoms of a panic attack.

4 **Explain** why the endocrine system is referred to as a communications system.

5 **Explain** why telling someone to 'calm down' during a panic attack will not stop their symptoms. (HINT: Are they able to control their hormones?)

Analyse

6 **Compare** a hormonal response and a nervous response. **Describe** one advantage for each system.

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

2.7 Homeostasis regulates through negative feedback

Learning intentions

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

- describe the advantage of homeostasis
- explain how hormones regulate blood glucose.

Key ideas

- The body needs to detect and correct changes in its levels of nutrients, water and temperature to stay healthy.
- The process of regulating the internal conditions of the body is called homeostasis.
- Negative feedback occurs when the body responds in a way that removes the initial stimulus.

Scientists have not yet discovered another planet that humans could inhabit. Humans can only survive in very specific environments. Our bodies have particular requirements, including the right amount of food, water and oxygen. If you were lost in a desert or in freezing temperatures, your body would try to maintain a temperature of about 37°C at all times, to keep all cells working efficiently. This 'business as usual' approach of responding to stimuli to maintain a stable state is called **homeostasis**.

homeostasis
the process by which the body detects and responds to stimuli to ensure a stable internal state is maintained

Figure 1 Homeostasis is your body's ability to regulate and maintain a stable condition (balance) inside your body, regardless of changes to the external environment.

Homeostasis

To maintain homeostasis, your body uses a mechanism that is similar to a thermostat in a heater. When temperature receptors on your skin and in the hypothalamus of your brain detect cooling down (stimulus), a message gets sent to a variety of effectors around your body. Effectors are glands or muscles that cause a change in the way your body functions. This may include muscles to make you shiver (to warm up) or blood vessels to redirect the flow of warm blood to the important organs in your body (heart, liver and brain).

If the temperature receptors detect that you are too hot (stimulus), then the effectors include your sweat glands and blood vessels.

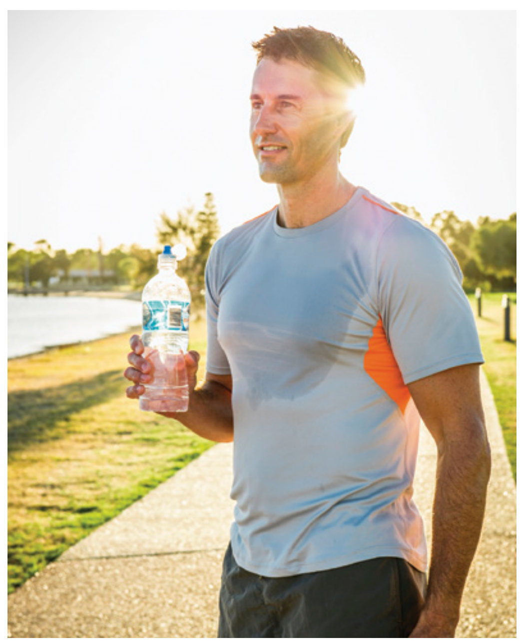


Figure 2 When your body is stimulated by heat, homeostasis ensures you cool down by sweating.

EXPERIMENT

2.7: Experiencing homeostasis
Go to page **185**.

Your body responds by sending more blood, which is carrying heat, to your skin, where sweat is evaporating, carrying away the heat and cooling you down. This a **negative feedback mechanism** – the stimulus causes the effectors to respond in a way that negates or removes the stimulus. If you are too hot, then your body tries to cool you down. If you are too cold, then your body works to warm you up.

Hormones at work

The rate of hormone production and secretion is often regulated by a negative feedback mechanism. If a stimulus is received that indicates something in the body is happening 'too much', the body has receptors to detect it. The body responds by producing a hormone to remove the stimulus and return the body to normal.

Blood glucose

As you eat, food gets broken down into smaller nutrients. All carbohydrates get broken down into simple sugars, including glucose. These glucose molecules travel through your blood and provide energy for cellular respiration (the reaction of glucose with oxygen to produce carbon dioxide, water and ATP). Too much glucose in the blood is not healthy, because it causes water to be lost from cells through osmosis. Your body tries to control the amount of glucose in your blood. If the concentration of glucose in your blood is too high (stimulus), then receptors in the pancreas detect it.

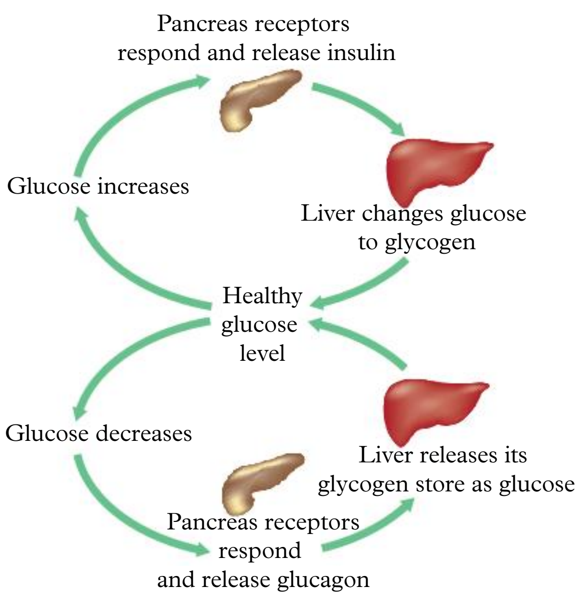


Figure 4 The pancreas and the liver work together to maintain healthy glucose levels in the body.

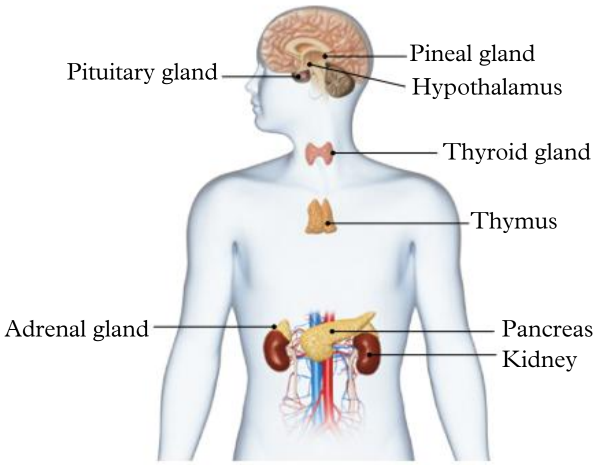


Figure 3 The pancreas is the endocrine organ responsible for the regulation of blood glucose levels.

They then release a hormone called insulin into the blood. Insulin travels throughout the body to insulin receptors on the target muscle and liver cells. These cells then act as effectors and remove glucose from the blood. This causes the blood glucose to decrease, removing the original stimulus. This is an example of negative feedback.

If blood glucose levels are too low, your body will use negative feedback to restore levels to a homeostatic state. Low glucose levels are detected by receptors in the pancreas (stimulus). This time, the hormone glucagon is released into the blood. Receptors for glucagon are also found on the effector cells in the liver and muscles. Glucagon binding to the receptors causes the muscle and liver cells to release stored glucose into the blood (response), increasing the amount of blood glucose once again.

negative feedback mechanism
a regulatory loop in which the stimulus causes a response that acts in the opposite direction to whatever is being regulated

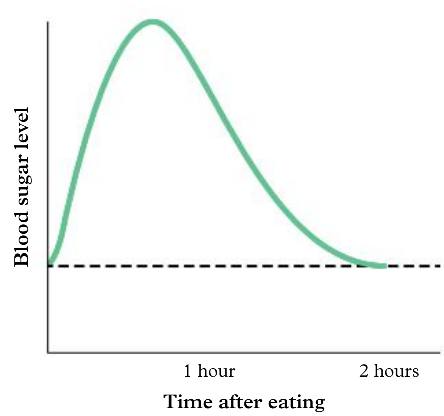


Figure 5 After you eat, your blood glucose levels increase. The body's response is to release insulin, which causes the muscle and liver effectors to remove the glucose and restore homeostasis.

Figure 6 Water controls the chemical reactions that occur in cells.

Water regulation

You may have noticed that when you drink a lot of water, you need to visit the bathroom in the next hour. Your body uses homeostasis to control the balance of water in your body. Water is needed to control all the chemical reactions that occur in the cells. If there is too much or too little water, these chemical reactions will be affected and the cells can become damaged.

The water balance in your body is tightly controlled by the hypothalamus in your brain. If it has been a hot day, or you have been doing physical exercise and sweating, then your body may have lost a lot of water. Receptors in the hypothalamus of the brain detect changes in fluid levels in your blood and send a message to the pituitary gland at the base of your brain. The pituitary gland releases a chemical messenger called antidiuretic hormone (ADH) into your blood.

This hormone travels all around your body until it reaches target effector cells in your kidney. The ADH binds to the receptors on the effector cells, causing them to reabsorb extra water from your urine. This makes your urine more concentrated or darker in colour. The extra water that was reabsorbed goes back into the blood, keeping the blood volume high. This is a form of negative feedback, because the response (reabsorbing water from the urine and returning it to the blood) results in a decrease of the stimulus (improving water levels in the blood).

Drinking a lot of water causes the blood volume to increase. This is also detected by receptors in the hypothalamus. This time the message to the pituitary gland is 'STOP producing ADH'. The lack of ADH is detected by the effector cells in the kidney, and they stop reabsorbing water from the urine. This means the urine has more water in it, and it becomes very clear and diluted.

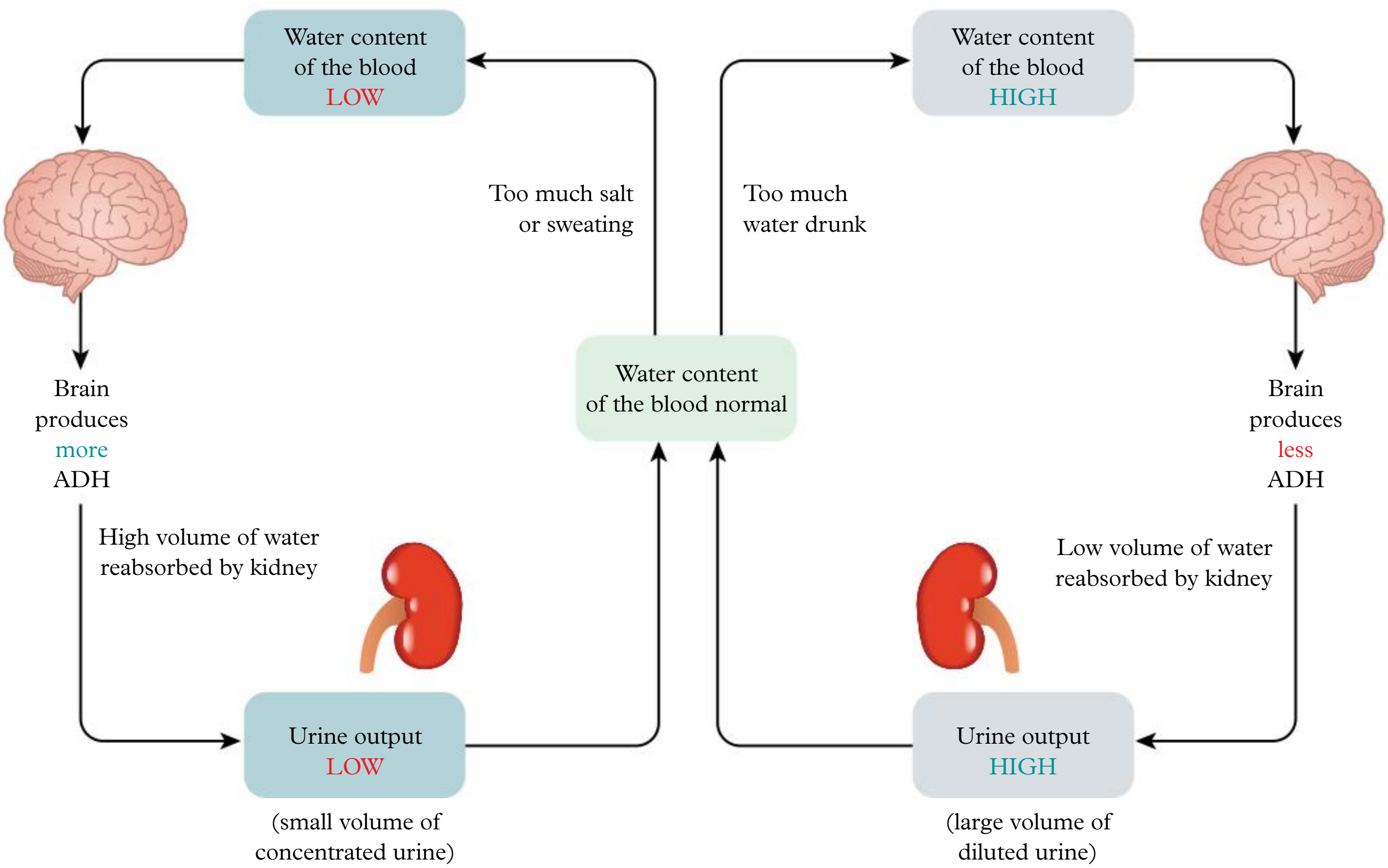


Figure 7 Water regulation in the human body

Oxygen and carbon dioxide homeostasis

Have you ever wondered why you become puffed when running a race? Oxygen and carbon dioxide in the blood are under strict homeostatic control. You need the oxygen for cellular respiration in a cell. Carbon dioxide is the waste product of this reaction.

Sprinting during a race causes the muscle cells in your legs to use a lot of glucose and oxygen and to produce a lot of carbon dioxide. The muscle cells release the carbon dioxide into the blood, where it forms carbonic acid. This is not good for your body. The acid content of the blood is measured by receptors in the medulla in the brain stem. If the level is too high from excess carbon dioxide, a message is sent through the nervous system to the muscles that control your breathing. This causes the diaphragm to move faster, increasing the rate of your breathing and making you feel puffed.

The message also goes to the heart to make it beat faster. This makes the blood move faster, carrying the carbon dioxide to the lungs where it can be removed by breathing out. These two responses act as negative feedback, removing the stimulus of high levels of carbon dioxide in the blood.

Meditation often involves sitting or lying down and relaxing. This means the level of cellular respiration in muscles is low. Little oxygen is used and little carbon dioxide is produced. As a result, the levels of carbon dioxide in the blood decrease. The receptors in the medulla once again detect the change from the homeostatic state and signal the heart to slow its beat and the lungs to slow their breathing.

Figure 8 After a race, you may be puffed.

2.7 Check your learning

Retrieve

1 **Define** the term 'homeostasis'.

2 **Identify** the stimulus, location of receptors, effectors and response to high body temperature.

Comprehend

3 **Describe** how your body responds to cold weather.

4 **Describe** how your blood sugar level changes when you eat.

5 **Describe** how your body responds to low blood sugar levels.

Analyse

6 If a negative feedback loop reduces the effect of a hormone, **infer** what a positive feedback loop should do.

Apply

7 **Discuss** how and why your body responds to the following:

  a drinking a bottle of water

  b swimming 15 m under water

  c swimming in the ocean on a cold day.

8 In type 1 diabetes, cells in the pancreas are unable to produce insulin. **Predict** what effect this would have on blood glucose levels.

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

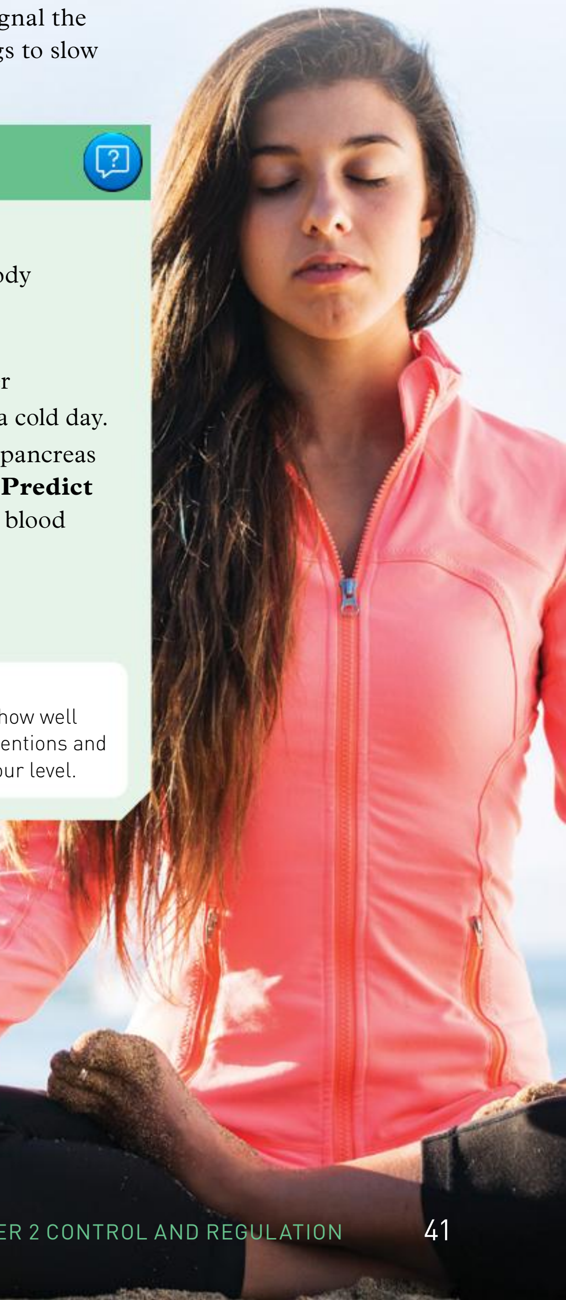


Figure 9 When you meditate, the carbon dioxide levels in your body decrease.

2.8 Sometimes things go wrong with homeostasis

Learning intentions

By the end of this topic, you will be able to:
- explain what causes type 1 diabetes
- define and contrast hyperglycaemia and hypoglycaemia
- describe what occurs when somebody experiences hypothermia.

Key ideas
- Negative feedback can be disrupted.
- Type 1 diabetes is caused by the disruption of glucose homeostasis.
- Becoming too cold (hypothermia) can disrupt homeostasis.

Homeostasis is important in maintaining the health of your body. When it malfunctions, it can cause other parts of the body to stop functioning properly. If undetected, it can even cause death.

Type 1 diabetes

Diabetes is a disease caused when a single hormone (insulin) cannot be produced by the body. As discussed in Topic 2.7, when a person eats, many of the foods are broken down into simple sugars, such as glucose. The glucose is absorbed into the blood stream. If the level of glucose in the blood stays too high, then it can cause problems, so the body relies on the release of insulin to remove the glucose and store it in the liver and muscle cells.

Some people are unable to produce insulin because their body has destroyed the pancreas (beta) cells that detect and produce this hormone. This means that the body is unable to remove the glucose from the blood. When the level of glucose in the blood is not regulated, it can disrupt other functions in the body. Approximately 1 person in every 183 people between the ages of 0–24 has **type 1 diabetes**. The average age of onset is 13 years old.

Hyperglycaemia

When the beta cells are destroyed, the amount of glucose in the blood increases to beyond normal levels (4.0–7.8 mmol/L). This is called **hyperglycaemia**. As the amount of glucose increases, the body tries to remove the sugar in other ways. It can be released in the mouth saliva, causing fruity-smelling breath. If can also cause the mouth to feel dry because extra sugars will pull water from the surrounding tissues. The high blood glucose will also affect the kidneys, causing more urine to be produced.

This means a person with hyperglycaemia will need to urinate more often. Because they are losing more water in the urine, a hyperglycaemic person will feel thirsty all the time. They will feel like they need to drink many litres of water each day. The person experiencing hyperglycaemia can also feel tired, have a headache and blurred vision. If it is not treated, the person can become confused and fall into a coma. Hyperglycaemia can be controlled by replacing the insulin in the body with an injection or via an insulin pump. This artificial insulin works the same way as the body's normal hormone, causing the liver and muscle cells to take in the glucose.

Hypoglycaemia

Hypoglycaemia occurs when the amount of glucose in the blood becomes too low. This can be caused by not eating enough, or by injecting too much insulin into the body. This causes the liver and muscle cells to remove all the glucose from the blood.

If the amount of glucose in the blood becomes too low, the body will not be able to use glucose to produce energy. This can cause sweating, clamminess, headaches, confusion, tiredness and difficulty speaking. If it is not treated, the person can pass out and eventually die.

Mostly, hypoglycaemia can be treated simply by consuming glucose-rich foods and drinks like jelly beans and apple juice.

Blood sugar technology

A person with diabetes needs to be aware of their blood glucose levels so that they can control them through diet and administration of insulin. A regular finger-prick test can test the amount of glucose in a drop of blood.

hypoglycaemia
when there are low levels of glucose in the blood which can occur when the body has too much insulin

type 1 diabetes
an autoimmune disease in which the immune system attacks the insulin-producing cells in the pancreas

hyperglycaemia
when there are high levels of glucose in the blood which can occur when the body has too little insulin

hypothermia
the condition of having an abnormal, potentially dangerous, low body temperature

If blood sugar levels are not controlled, it can cause long-term effects, from kidney damage to blindness.

Technology has made it easier for people with diabetes to maintain nearer to normal blood glucose levels. Continuous glucose monitors are inserted into the abdomen or arm of the person. This technology can automatically check blood glucose levels and send the information to an app on the person's phone. An alarm will notify the person if the level is too high or too low. The person can then administer insulin or eat some glucose-rich foods.

People with diabetes can also access insulin pump technology that automatically releases insulin into the body. The amount of insulin delivered depends on how much food the person tells the pump they will eat and the person's blood glucose level received by the pump from the person's continuous glucose monitor. The use of the monitors and insulin pumps have replaced half of the body's blood glucose homeostasis.

Hypothermia

Hypothermia (hypo – too low, thermia – temperature) is caused by the body's temperature becoming too low. This can be caused by situations such as wearing clothes that are not warm enough, staying out in the cold (especially in wet clothing) or being in cold water for too long.

When the body's temperature starts to drop, homeostasis will cause the muscles to start moving and the body will start to shiver. The blood moves away from the skin (making it pale) and stays in the important organs, such as the heart, liver and brain. If the body continues to cool below 35°C, the person may become clumsy, slur their speech and become confused. Eventually, there is not enough energy for the body to keep shivering, and confusion may cause the person to think they are warm again. This is when hypothermia becomes most dangerous because the body temperature will drop quickly below the life-threatening 32°C.

It is important not to treat hypothermia by putting the person in a warm shower, heater or bath. This can cause the cold blood near the skin to rush back to the heart and brain, causing the person to become even colder. Instead, the person should have wet clothing removed and be warmed up slowly with warm blankets, wrapped warm water bottles or skin-to-skin contact.

Figure 1 Continuous glucose monitors can be used to automatically detect the amount of glucose in the blood.

Figure 2 Insulin pumps can be programmed to inject insulin automatically.

Figure 3 Early warning signs of hypothermia

2.8 Check your learning

Retrieve

1 **Define** the following terms.
   a hypoglycaemia
   b hyperglycaemia
   c hypothermia
2 **Recall** what causes type 1 diabetes.

Comprehend

3 **Describe** how your body responds to high blood glucose levels.
4 **Describe** how your body responds to low blood glucose levels.
5 **Describe** how your body responds to extremely low temperatures.
6 **Describe** why drinking apple juice can help a person with hypoglycaemia.
7 **Explain** why you should not put a person with hypothermia in a hot bath to warm up.

Apply

8 **Identify** if it is one or more of the stimulus, the receptors or the effectors that is lost in type 1 diabetes. **Justify** your decision (by identifying the stimulus, the receptor and the effector in blood glucose homeostasis, describing the function of each in blood glucose homeostasis and comparing this to the effect of type 1 diabetes).

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

//SCIENCE AS A HUMAN ENDEAVOUR//

2.9 Hormones are used in sport

Learning intentions

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

- describe the function of erythropoietin and how athletes may use it to improve their performance in sporting events.

Erythropoietin is a hormone normally produced by the kidneys to increase the number of red blood cells in the body. Athletes can use this version of a negative feedback mechanism naturally or artificially to increase their performance on the sporting field.

Many athletes and sporting clubs spend months training high in the mountains to help their performance in competitions. The air in the mountains is much thinner. Although it is still 21 per cent oxygen, it is harder for a person to fill their lungs as the particles in the air are spread out further. As a result, when a person first arrives at high altitude, their body struggles to get enough oxygen. This can make the person feel tired, because they are unable to burn the glucose in aerobic cellular respiration.

Negative feedback in action

The body normally produces just enough red blood cells to carry oxygen around the body. When red blood cells die, a hormone called erythropoietin is produced by the kidneys.

The erythropoietin travels through the blood to receptors in the bone marrow. The effector bone marrow cells then produce more red blood cells to replace those lost.

Exercising at a high altitude stimulates the body to react as though there are not enough red blood cells to carry oxygen to the muscles. Erythropoietin is produced, causing the bone marrow to make extra red blood cells. It takes about three weeks for the extra cells to become noticeable. When the athlete returns to sea level to compete, the red blood cells remain active for up to a month. This means the athlete's blood is more efficient at carrying oxygen to muscles, making the athlete less likely to become fatigued (tired). Training at a high altitude uses the negative feedback mechanism to the athlete's advantage.

Some athletes bypass high-altitude training and inject erythropoietin directly into their blood. This is called blood doping. However, the amounts of hormone introduced into the blood are not controlled. This can cause an over-production of red blood cells, which strains the heart. The athlete is at risk of a heart attack or a stroke.

Figure 1 Training at a high altitude can increase an athlete's performance.

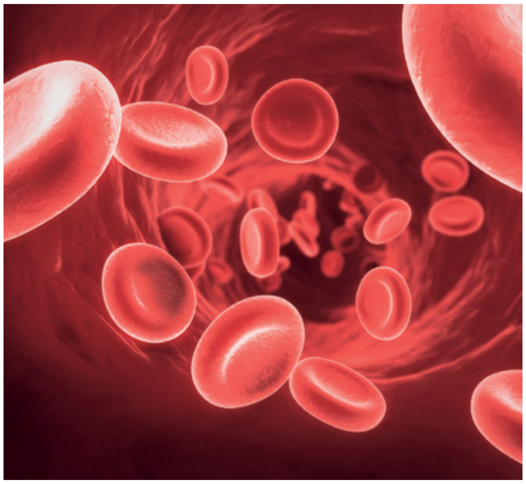


Figure 2 Erythropoietin increases the production of red blood cells.

Drug testing

Erythropoietin was first synthesised in the laboratory in the 1990s. Unfortunately, it was 10 years before drug testing could distinguish the artificial hormone from naturally occurring erythropoietin. In 2002, at the Winter Olympic Games in Salt Lake City, United States, the first athlete was identified as having a version of erythropoietin in their urine and blood.

Figure 3 In 2013, Lance Armstrong admitted to injecting erythropoietin to help him win world cycling events.

Medical uses of erythropoietin

Erythropoietin is produced in the kidneys. Any disease that affects kidney function will also affect the production of erythropoietin. As a result, a person with kidney disease will also have low levels of red blood cells. This is called anaemia. Symptoms of anaemia are a pale appearance and feeling tired when exercising. Regular injections of erythropoietin will increase the production of red blood cells and improve the person's health.

Figure 4 Anaemia can make you feel tired when exercising.

2.9 Test your skills and capabilities

Evaluating the ethics in sports

Sporting competition prides itself on fairness for all competitors. There are many ways to improve an athlete's chances of winning a competition, including training, special diets, shaving body hair and wearing special clothing that reduces air resistance. Some athletes undergo surgery to improve their ability to compete. This can include a golfer having laser eye surgery. A runner who has asthma is allowed to use a Ventolin inhaler, but other athletes are not permitted to use hormones to speed their recovery from an injury.

Evaluate the ethics of cheating in sports by deciding which of the following situations should be allowed and which should be banned. In each situation, **justify** your decision (by describing how the athlete would be advantaged, describing the potential dangers to the athlete, describing whether all athletes would have equal access, and deciding whether the situation could be described as cheating).

1 An athlete takes a dietary supplement that maximises their performance.
2 A swimmer wears an expensive swimsuit that minimises water resistance.
3 An athlete has genetically modified muscles.
4 An athlete takes hormones that increase recovery after injury by increasing muscle mass.

//SCIENCE AS A HUMAN ENDEAVOUR//

2.10 Pathogens cause disease

Learning intentions

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

- provide examples of pathogens
- describe the scientific discoveries that led to the development of the 'germ theory'.

pathogen
a microbe that can cause disease

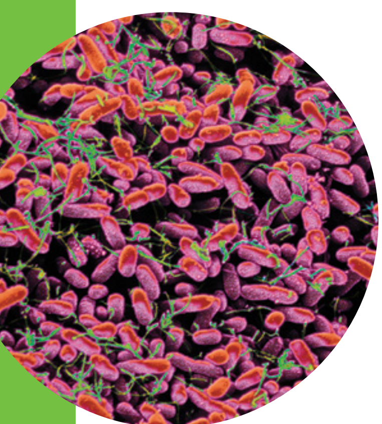


Figure 1 Some bacteria keep us healthy. Other bacteria are pathogens and interfere with the natural functioning of our body.

Infectious pathogens can disrupt the normal functioning of the body and cause disease. There are many types of pathogens, including bacteria, fungi, protozoans and viruses. Koch's postulates are used to provide evidence that a pathogen causes a disease. Penicillin and other antibiotics can be used to kill bacteria, but not viruses or other pathogens.

One of the first people in Western medicine to question the accepted idea of supernatural causes of disease was Hippocrates. He concluded that something in the air, soil, water and food caused diseases in humans and animals. His work was followed up by Claudius Galen, who was a doctor to the gladiators, and used animal dissections to explore anatomy.

Girolamo Fracastoro was an Italian astronomer and doctor who was one of the first to suggest that disease could be transmitted from person to person via small, invisible particles. He theorised that these particles could travel through the air, via contaminated clothing or by direct contact with the sick person. It took 200 years and the discovery of the microscope to confirm his theories and to develop the 'germ theory' used today.

Germ theory states that many diseases are caused by the presence and actions of specific microorganisms. These microorganisms are called **pathogens**. Germ theory was confirmed by Louis Pasteur and Robert Koch.

Robert Koch went on to develop a set of rules, known as Koch's postulates, that provide evidence that a pathogen causes a disease.

1 The microorganism or other pathogen is present in all cases of the disease.
2 The pathogen can be isolated from the diseased host and grown in the laboratory.
3 The pathogen from a pure culture causes the disease when inoculated into a healthy, susceptible laboratory animal.
4 The pathogen is re-isolated from the new host and is shown to be the same as the originally inoculated pathogen.

Australian scientists Barry Marshall and Robin Warren followed these postulates when they researched stomach ulcers in 1984. Together they discovered that a bacterium (*Helicobacter pylori*) was found in all patients with stomach ulcers. Most doctors at the time thought that no bacterium could survive in the acidic environment of the stomach. Marshall and Warren isolated the bacterium and injected it into mice, causing the disease in the mice. Unfortunately, many doctors still did not believe the research, so Barry Marshall ignored laboratory safety and swallowed a culture of the bacteria, causing the disease in himself.

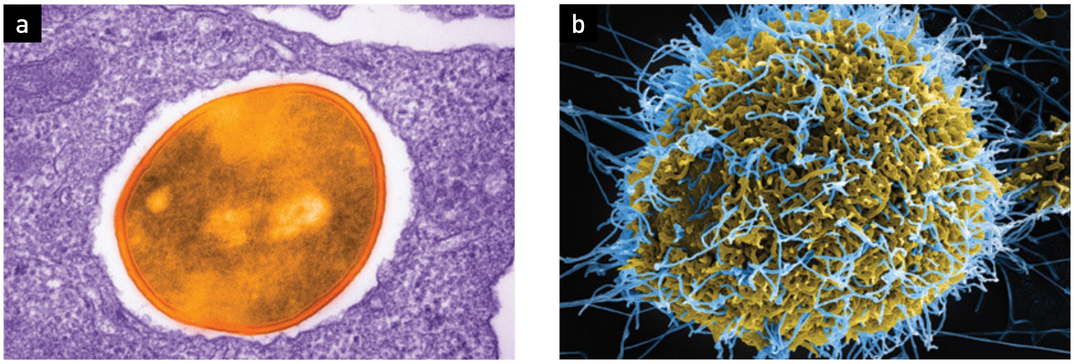


Figure 2 Most infections are caused by microscopic pathogens such as bacteria or viruses.
a Bacteria are very small cells that are able to reproduce by themselves. They can release toxins that affect the normal functioning of our body. **b** Viruses are much smaller than bacteria and are unable to reproduce by themselves. Instead, they invade the host's cells and use the organelles to make new copies of themselves. This stops the host's cells from functioning properly.

CHALLENGE
2.10A: Investigating pathogens
Go to page **186**.

EXPERIMENT
2.10B: Investigating germ theory
Go to page **187**.

Figure 3 Louis Pasteur's experiments found that microorganisms in milk were killed by heat. This process is called pasteurisation (named after Pasteur) and is still in use today.

Treatment with antibiotics killed the bacteria and cured his stomach ulcer. Barry Marshall and Robin Warren were awarded the Nobel Prize in Physiology or Medicine in 2005.

Antibiotics

Before antibiotics were discovered, a single scratch from a prickle on a rose bush could become infected and kill a person.

In 1928, Alexander Fleming was trying to grow bacteria in his laboratory. When he returned from holidays he discovered that some Petri dishes he had left open on the bench were growing a mould similar to that found on bread. There were no bacteria growing near the mould. Being a good scientist, Fleming recognised that further investigation was necessary. He performed some experiments and discovered that the *Penicillium* mould was releasing a chemical that killed bacteria. Australian scientist Howard Florey was then instrumental in developing penicillin into a form that could be mass-produced. Both scientists were awarded the Nobel Prize in Physiology or Medicine for their work.

Penicillin works by breaking down the cell walls of bacteria. As human cells do not have a cell wall, they are unaffected. This means that penicillin will kill the bacteria in your body but not kill your own body cells. Viruses do not have cell walls. Instead, they have a protein coat that surrounds and protects them. This means penicillin does not affect viruses, such as influenza, coronaviruses or the common cold.

Most viruses cannot be treated by any readily available medicines.

Figure 4 Robin Warren (left) and Barry Marshall (right)

2.10 Test your skills and capabilities

Identifying assumptions

Scientists are always asking questions and challenging what they know. Robin Warren and Barry Marshall asked questions and challenged the assumption that stomach ulcers were caused by stress. Everyone makes assumptions (accepting that something is true or certain without evidence) based on past experiences. It is a way of saving time and energy thinking. We assume that the sun will rise in the morning, that the chair we sit on will not collapse and that food we have cooked will be hot. Making assumptions is not always a bad thing, as long as we are aware that we are making them. Asking questions is a way of identifying assumptions that are not true.

1 **Identify** the question that Robin Warren and Barry Marshall asked about stomach ulcers.
2 **Identify** how Warren and Marshall used each of Koch's postulates to find the cause of stomach ulcers.
3 **Identify** the assumption that other doctors had made about the cause of stomach ulcers.
4 **Identify** one assumption that you have made in the past week.
5 **Describe** the evidence you would need to convince yourself that your assumption in question 4 was incorrect.
6 **Describe** an invention or behaviour you would change if your assumption in question 4 was incorrect.

2.11 The immune system protects our body in an organised way

Learning intentions

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

- describe some of the body's first-line defence mechanisms against infection
- compare naturally acquired immunity with vaccinations.

Key ideas

- The immune system acts to physically prevent pathogens entering your body.
- Pathogens that enter the body are identified and destroyed by the immune system.

immune system
a system of organs and structures that protect an organism against disease

white blood cell
an immune system cell that destroys pathogens

The role of your **immune system** is to protect you against foreign invaders by physically stopping them from entering your body, and to identify and attack them if they do manage to enter. Your immune system has three lines of defence against pathogens, each with a different role.

First line of defence

The first line of defence stops pathogens from getting inside your body (Figure 1). It consists of the skin and mucous membranes.

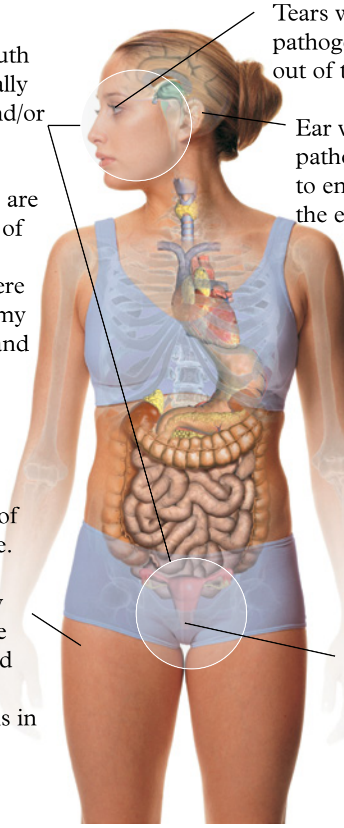


Figure 1 The skin and mucous membranes are the first line of defence against pathogens.

Second line of defence

Viruses, unlike bacteria, contain a protective coating that allows them to more easily slip through the first line of defence. If a pathogen gets inside your body, the body tries to remove it in one of two ways.

First, a general 'seek and destroy' approach occurs regardless of the type of pathogen. This is called a general or non-specific immune response. The key parts of the non-specific immune response are:

> blood clotting – to stop additional infection through skin damage
> inflammation – to increase the number of blood cells reaching an infected area
> fever – some pathogens cannot survive at high temperatures, so heating up the body is one way to destroy them.

Second, **white blood cells** are produced by the body to destroy pathogens. Inflammation increases the amount of blood reaching the infected area, so more white blood cells are able to attack the pathogen. The white blood cells may also release chemical messengers that increase the amount of fluid in the infected area, causing swelling.

There are different types of white blood cells. Each type has its own role but they all work together. **Phagocytes** (Greek for 'cells that eat') are part of the non-specific immune response. They surround and absorb pathogens, destroying them in a process called phagocytosis (Figure 2).

Third line of defence

Any pathogens that survive the non-specific secondary response are targeted according to their type. This is called a specific immune response.

CHALLENGE

2.11: Modelling infection and vaccination
Go to page **188**.

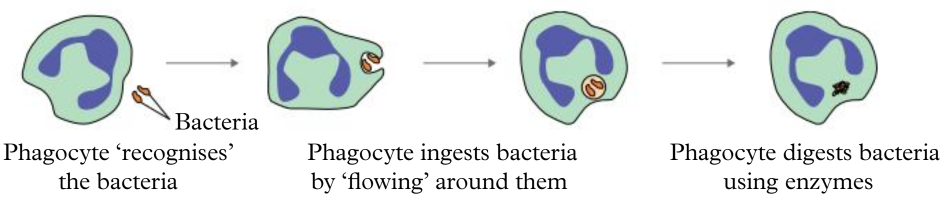


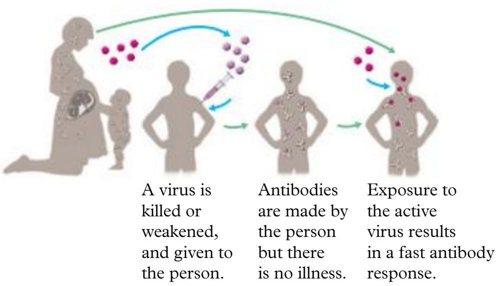
Figure 2 The process of phagocytosis

The specific immune response has two forms of attack. **B cells** produce special molecules called **antibodies**. These antibodies fit exactly onto a specific part of the pathogen (Figure 3). Each antibody will fit only one section of the pathogen. This causes the pathogens to become locked together and stops them invading.

T cells then recognise the same specific pathogen and attack and kill it. B and T cells may take up to a week to recognise and destroy a pathogen. This is why recovering from an illness takes time.

Both B and T cells keep some **memory cells** alive, just in case the pathogen tries to invade again. This means the pathogen will be attacked and killed before it can cause damage a second time. Your body will be protected from reinfection in the future. You are now **immune**.

Unborn babies obtain some natural immunity by receiving antibodies through the placenta from the mother. Antibodies are also passed to babies through breast milk.



Another way to acquire immunity is by ingestion or injection with specific small parts of the pathogen. This is called **vaccination**, or inoculation. A vaccine can be made up of:

- the dead pathogen
- a living but non-virulent (weakened) form of the pathogen
- parts of the broken-up pathogen
- genetic material from a viral pathogen.

Through vaccination, a person makes antibodies and memory cells that will recognise the pathogen in the future, which usually leads to immunity. Vaccinations are often given as a preventive measure. For instance, the influenza vaccine is recommended for people over 65 years of age because complications from influenza can be life-threatening in older people. Vaccination can also be given when there is an urgent need to provide immunity, such as preventing COVID-19. For example, the modified genetic material from the SARS-CoV-2 coronavirus can be used for vaccination. This means a person will have antibodies and T cells already activated in their body to prevent the virus from causing damage and COVID-19 symptoms.

Figure 4 A person can become protected or immune actively through vaccination, or passively by antibodies being passed on to them in breast milk from their mother when they are a baby.

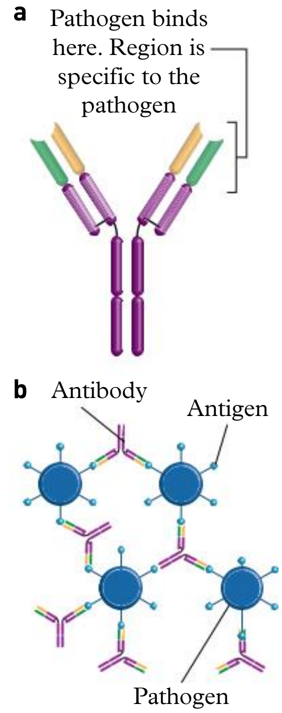


Figure 3 a Each antibody has a region that is specific to a particular pathogen. **b** Antibodies cause pathogens to clump together.

phagocyte
an immune system cell that surrounds, absorbs and destroys pathogens

B cell
an immune system cell that produces antibodies in response to pathogens

antibody
a molecule produced by B cells that binds to a specific pathogen

T cell
an immune system cell that recognises and kills pathogens

memory cell
an immune system cell produced in response to an infection; retains the memory of how to fight the pathogen

immune
able to fight an infection as a result of prior exposure

vaccination
an injection of an inactive or artificial pathogen that results in the individual becoming immune to a particular disease

2.11 Check your learning

Comprehend

1 **Describe** the body's major first line of defence.
2 **Describe** one other way the body can prevent pathogens from entering.
3 **Describe** in your own words how the non-specific immune response works.
4 **Describe** how a vaccine prevents a person from 'catching' a disease.

Analyse

5 **Compare** the second and third levels of defence.
6 **Compare** the different types of vaccines.

Apply

7 Newborn babies cannot be vaccinated against whooping cough until they are 2 months old. The antibodies in breast milk are not enough to protect them from this deadly disease. **Discuss** why it is important for everyone who comes into contact with a newborn baby to be vaccinated against whooping cough.

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

2.12 Sometimes things go wrong with the immune system

Learning intentions

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

- describe the immune response during an allergic reaction
- describe the common symptoms of rheumatoid arthritis and type 1 diabetes
- describe the cause of HIV and relate it to the development of AIDS.

Key ideas

- Allergies result from an overactive immune system.
- Autoimmune diseases such as type 1 diabetes and rheumatoid arthritis are caused by the immune system attacking body cells.
- HIV is a virus that specifically attacks T cells, resulting in acquired immune deficiency syndrome (AIDS).

The immune system coordinates attacks on pathogens that are trying to disrupt the body. The coordination of all the cells and chemical molecules is very complex, and can easily be disrupted.

Hay fever and other allergies

Allergies result when your immune system mistakes a harmless substance as dangerous. This means the body overreacts. A common example is plant pollen, mainly from grass but also from trees, which can cause hay fever. When the pollen gets in your eyes or nose, your second and third lines of defence start attacking it.

Inflammation occurs, resulting in an increased amount of blood reaching the area. Fluid leaks out of the blood vessels and the area becomes red and swollen. This also contributes to a runny nose and watering eyes, as your body tries to flush out the pollen.

Phagocytes also invade the area in an attempt to destroy the pollen. If you have been exposed to the pollen before, then your body will already have antibodies that speed up this reaction. In extreme cases, the person's throat will swell shut, making it difficult to breathe. The large amount of fluid leaking from the blood vessels can also cause the blood vessels to collapse. This life-threatening response is called **anaphylaxis**.

allergy
an overreaction by the immune system in response to pollen, dust or other non-pathogens

anaphylaxis
a life-threatening overreaction by the immune system to a normally harmless substance

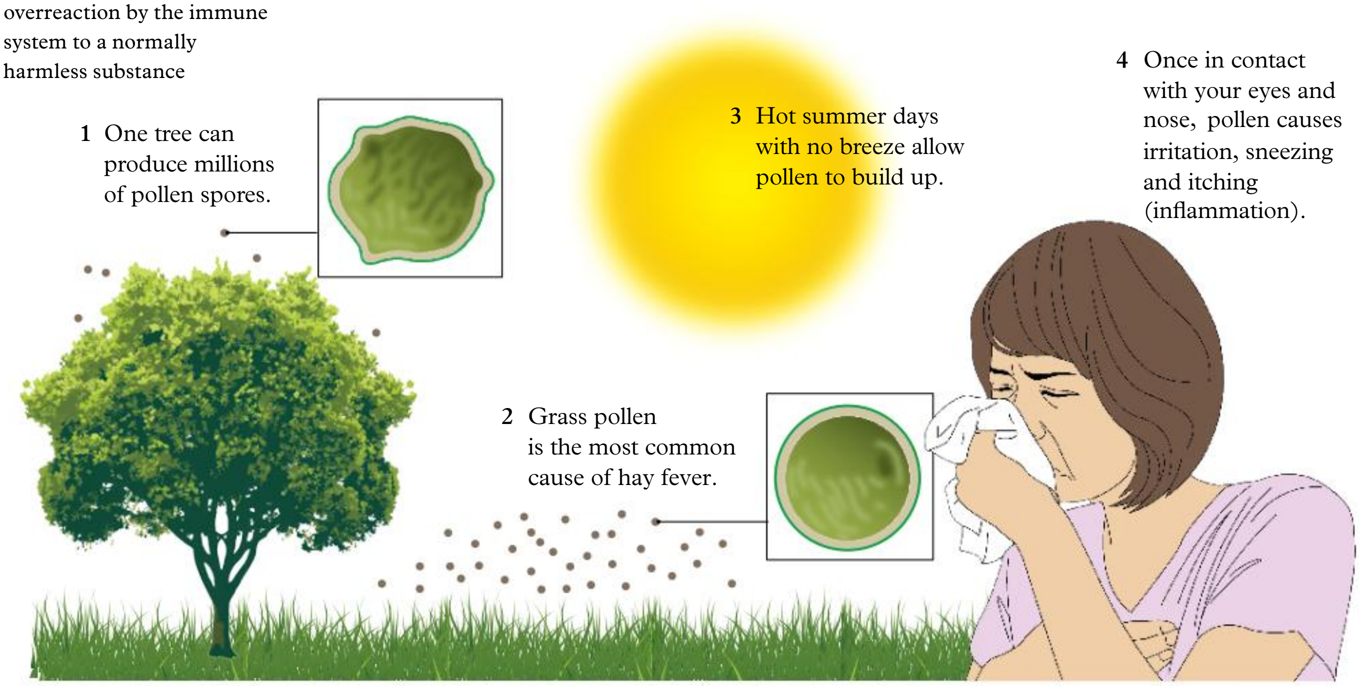


Figure 1 How hay fever happens

Figure 2 Epipens deliver adrenalin to people suffering anaphylactic shock.

Autoimmune diseases

Autoimmune diseases are a group of diseases that result from your body's immune system identifying healthy parts of your own body as a pathogen. **Rheumatoid arthritis** is an autoimmune disease in which the body produces B and T cells that attack the joints of the body. B cells produce antibodies, and T cells try to destroy the synovial membrane that lines the joint. This causes the joint to swell with fluid, which causes heat and pain for the sufferer.

Figure 3 Inflammation causes the joints of rheumatoid arthritis sufferers to swell and become painful.

Type 1 diabetes is also caused by an autoimmune reaction against the cells in the pancreas that produce insulin. As a result of attack by B cell antibodies and T cells, these pancreatic cells are destroyed. This means the person is unable to control their own blood glucose levels and instead must test their glucose levels regularly and inject artificial insulin when it is needed.

HIV causes AIDS

The human immunodeficiency virus (HIV) infects a special type of T cells in the immune system. This makes the whole immune system ineffective. A person with HIV has a weakened immune system. This causes them to develop a range of infections that a normal immune system would be able to destroy easily. For example, simple fungal infections, viral eye infections and diarrhoea (loose bowel motions) can make a person infected with HIV very sick. Collectively these symptoms are called acquired immune deficiency syndrome (AIDS). There are many drugs that can be used to prevent a person infected with HIV from developing AIDS.

rheumatoid arthritis
an autoimmune disease in which the immune system attacks the joints of the body

Figure 4 HIV is detected using a blood test.

2.12 Check your learning

Comprehend

1 **Explain** why hay fever causes a runny nose and watery eyes.

2 **Explain** why hay fever is always worse the second time you are exposed to pollen.

3 **Explain** why a person with rheumatoid arthritis has swollen finger joints.

4 **Explain** why people with type 1 diabetes are unable to produce their own insulin.

5 **Explain** why eating even a small quantity of peanuts can cause death in some people.

Analyse

6 **Contrast** HIV and AIDS.

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

CHAPTER 2 REVIEW

CONTROL AND REGULATION

Retrieve

1 **Identify** which of the following is the stimulus.
- A a target cell that has a receptor
- B a hormone released into the bloodstream
- C a change in the environment that disrupts homeostasis
- D a response by the body that restores the homeostatic balance

2 **Identify** which of the following cells produce antibodies.
- A B cells
- B phagocytes
- C T cells
- D viruses

3 **Identify** which of the following is not a pathogen.
- A fungi
- B bacteria
- C adrenalin
- D yeast

4 **Define** the following terms.
- a stimulus
- b homeostasis
- c pathogen

5 **Complete** Figure 1 by **identifying** the missing labels for parts of the neuron.

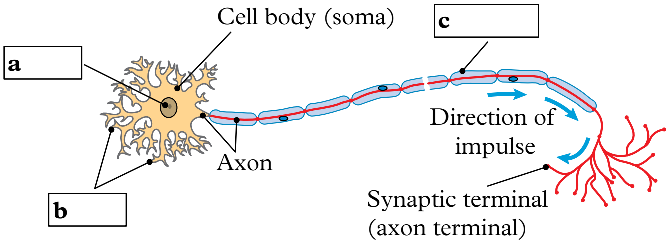


Figure 1 A typical neuron

6 **Identify** the four lobes of the brain and **state** their functions.

Figure 2 The cerebrum (the large pink area of the brain) is divided into four lobes.

7 **Identify** the early warning signs of hypothermia that are missing in Figure 3.

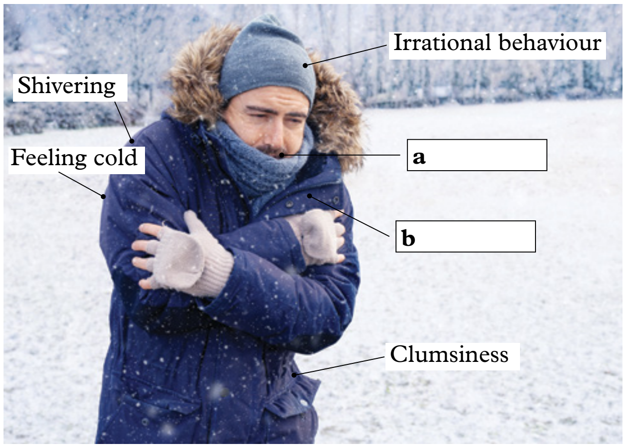


Figure 3 Early warning signs of hypothermia

8 **Name** two glands in humans that produce hormones.

9 Complete this sentence by inserting the missing words. A person with diabetes has a problem with the hormone __________, which is secreted by the __________.

Comprehend

10 **Describe** three ways the human body can receive a stimulus from the environment.

11 **Explain** why the nervous system and the endocrine system are both described as communication systems.

12 **Describe** how hormones are transported in the body.

13 **Describe** three major features of the body's first line of defence.

14 **Describe** how an antibody is used by the body to prevent a pathogen from spreading around the body.

15 **Explain** why it is important to have certain vaccinations before travelling overseas. **Identify** two examples of diseases you may need to be vaccinated against.

16 **Explain** how the immune system's third line of defence remembers pathogens for when you are exposed to the pathogen a second time.

17 Use an example to **explain** how a negative feedback mechanism works.

18 When a person drinks a litre of water, their body produces extra urine. Use the concept of homeostasis to **explain** why.

19 **Explain** how the endocrine system assists your body to 'respond to the world'. **Explain** why your body also needs a nervous sytem.

Figure 4 Drinking water after exercising is an important part of homeostasis.

20 **Explain** why holding your nose might help you to swallow something that tastes awful.

21 In Canada in 2006, a woman fought off a polar bear with her bare hands when it attacked her son. She literally wrestled the bear and won! **Explain** why this reaction could be attributed to the hormone adrenalin.

22 Given that people have usually caught a cold before, **explain** why we continue to catch colds.

23 **Describe** in your owns words how the non-specific immune response works.

Analyse

24 **Compare** viruses, bacteria and protozoa, which are all pathogens.

25 **Contrast** the roles of the somatic and autonomic nervous systems.

26 **Contrast** hyperglycaemia and hypoglycaemia.

Apply

27 Your body is constantly monitoring and controlling the numbers of pathogens in and on it. **Discuss** what you can do to assist your body in controlling pathogens.

28 The hygiene hypothesis suggests that childhood exposure to microbes and certain infections helps the immune system develop. As a result of potentially being too hygienic, developed countries continue to see a rise in autoimmune conditions such as type 1 diabetes and rheumatoid arthritis. **Investigate** these conditions, and **outline** the role of the body's own immune response in causing the symptoms.

29 Transmission of pathogens can cause mass outbreaks of a disease and affect large numbers of people. Examples are COVID-19, HIV, the SARS virus, swine flu, and the outbreak of cholera in Zimbabwe. **Investigate** one disease and **explain** how it can spread so quickly. **Describe** what can be done to prevent the spread of such diseases.

Social and ethical thinking

30 Babies can be vaccinated against a wide range of diseases in the first months and years of their lives. They are not old enough to choose to be vaccinated, so the decision is made by their parents or guardians. **Investigate** and **identify** which vaccinations are available. **Describe** at least four secondary sources of information that are consistent with the effectiveness of vaccination for babies. **Justify** why your sources of information are valid.

31 A person with Alzheimer's disease can often forget what has happened in the past 30 minutes. An example of this is forgetting they have already eaten their lunch. This means the person can become very frustrated and upset if they think they are being refused food. Their carers may explain (many times) that the person has already eaten, but this can upset the person more, because they think they are being lied to. Other carers may lie to the person and say that lunch will ready in five minutes. This settles the person, who will often forget about eating in that time. **Determine** which approach you would use. **Justify** your decision by describing the factors you considered when making your decision.

Critical and creative thinking

32 **Create** a cartoon strip with at least five squares, illustrating a person receiving a stimulus and then responding.

33 **Create** a visual presentation on the role of the different types of white blood cells in attacking pathogens.

34 Alcohol blocks the production of ADH. Use critical thinking to **predict** the effect this will have on urine volume.

35 **Construct** a table that distinguishes between the different lines of defence.

36 Louis Pasteur found that heat could kill microorganisms in milk. This discovery is still in use today. **Investigate** the use of heat in killing pathogens.

a **Identify** two reliable sources.

b **Summarise** one use of heat.

Research

37 Choose one of the following topics for a research project. A few guiding questions have been provided, but you should add more questions that you wish to investigate. Present your report in a format of your own choosing.

» Artificial skin

Skin is one of the main ways a body protects itself from infections. It provides a barrier against almost all pathogens and helps to control the amount of water lost by the body. When a person is burned, they may lose several layers of their skin. This can increase the risk of infection and make it difficult to control body temperature and water levels. Investigate the work of Australian scientists Dr Fiona Wood and Dr Marie Stoner on skin regeneration, including spray-on skin.

- Explain why their area of research is so important.
- Explain how this research is related to the increase in bushfires that is expected to occur with global warming.

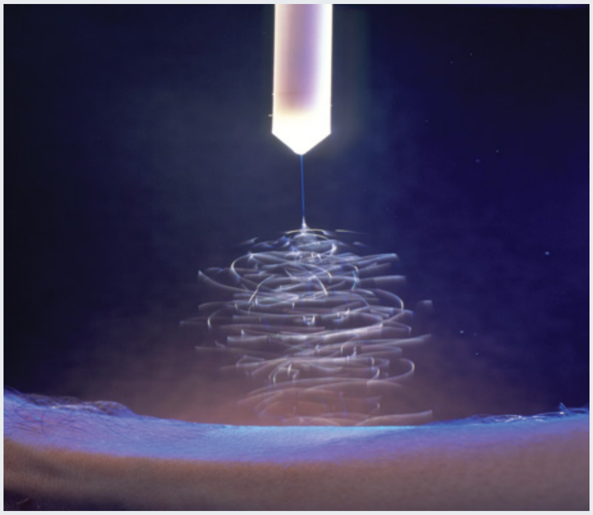


Figure 5 Spray-on skin being applied to an arm

» Preventing childhood diseases

Dr Helen Mayo was one of the first female medical doctors in Australia and made a significant contribution to the reduction of childhood mortality (death).

- Identify at least four accomplishments of Dr Mayo.
- Create a timeline of her studies, travel and accomplishments.
- Explain why Dr Mayo was considered 'unusual' for suggesting that mothers needed assistance to raise healthy children. (HINT: Consider the assumption that all women know how to be a mother and the level of education of women in 1913).

» Bionic ears and eyes

Professor Graeme Clark was instrumental in the development of the cochlear ear implant. This device is able to detect the soundwaves through a receiver on the outside of the skin. The information is transmitted to inside the cochlea where it is able to pass the message directly to the sensory nerves going to the brain.

- Compare the human-made cochlear implant to the way information is normal detected and transmitted by nerves.
- Research the bionic eye project.
- Identify and describe the way light is detected and the information transmitted to the part of the brain responsible for decoding the information.

Figure 6 Cochlear implant. Sound signals are passed from the processor behind the ear, to the round transmitter, to electrodes that have been implanted in the cochlea.

Chapter checklist

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

	I can do this.	I cannot do this yet.
• Identify the five senses and the receptors associated with each type of stimulus. • Describe how the structure of the sense organs is related to the type of stimulus they receive.	☐	☐ Go back to Topic 2.1 'Receptors detect stimuli'. Page 24
• Describe the passage of information through a neuron, across the synapse and to the next cell. • Explain how sensory, motor and interneurons communicate information around the body.	☐	☐ Go back to Topic 2.2 'Nerve cells are called neurons'. Page 28
• Describe the stimulus–response model. • Explain how reflex actions can provide responses that save lives.	☐	☐ Go back to Topic 2.3 'The nervous system controls reflexes'. Page 30
• Describe the roles of the central nervous system, peripheral nervous system, somatic nervous system and autonomic nervous system. • List the lobes of the brain and describe their main functions.	☐	☐ Go back to Topic 2.4 'The central nervous system controls our body'. Page 32
• Provide examples of diseases and problems affecting the nervous system. • Explain the relationship between the myelin sheath and multiple sclerosis.	☐	☐ Go back to Topic 2.5 'Sometimes things go wrong with the nervous system'. Page 34
• Describe the fight, flight or freeze response.	☐	☐ Go back to Topic 2.6 'The endocrine system causes long-lasting effects'. Page 36
• Describe the advantage of homeostasis. • Explain how hormones regulate blood glucose.	☐	☐ Go back to Topic 2.7 'Homeostasis regulates through negative feedback'. Page 38
• Explain what causes type 1 diabetes. • Define and contrast hyperglycaemia and hypoglycaemia. • Describe what occurs when somebody experiences hypothermia.	☐	☐ Go back to Topic 2.8 'Sometimes things go wrong with homeostasis'. Page 42
• Describe the function of erythropoietin and how athletes may use it to improve their performance in sporting events.	☐	☐ Go back to Topic 2.9 'Science as a human endeavour: Hormones are used in sport'. Page 44
• Provide examples of pathogens. • Describe the scientific discoveries that led to the development of the 'germ theory'.	☐	☐ Go back to Topic 2.10 'Science as a human endeavour: Pathogens cause disease'. Page 46
• Describe some of the body's first-line defence mechanisms against infection. • Compare naturally acquired immunity with vaccinations.	☐	☐ Go back to Topic 2.11 'The immune system protects our body in an organised way'. Page 48
• Describe the immune response during an allergic reaction. • Describe the common symptoms of rheumatoid arthritis and type 1 diabetes. • Describe the cause of HIV and relate it to the development of AIDS.	☐	☐ Go back to Topic 2.12 'Sometimes things go wrong with the immune system'. Page 50

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CHAPTER

3

REPRODUCTION

3.1

There are different ways of reproducing

> Define forms of asexual reproduction and sexual reproduction.
> Describe asexual and sexual reproduction in terms of genetic similarities between parent and offspring.
> Describe the influences of nature and nurture on the development of an individual.

3.2

Parental care affects survival

> Define fertilisation and contrast external and internal fertilisation.
> Compare how r-strategists and K-strategists reproduce and explain how their environment affects their reproduction.

3.3

The female reproductive system produces eggs in the ovaries

> Describe the main structures and functions of the female reproductive system.
> Explain the main processes involved in the menstrual cycle.

3.4

The male reproductive system produces sperm in the testes

- Define sexually dimorphic, testosterone and oviduct.
- Describe the main structures and functions of the male reproductive system.

3.5

Science as a human endeavour: Sometimes things go wrong with reproduction

- Define contraception, inbreeding and desexing.
- Describe some common problems of the human reproductive systems.

3.6

Plant sexual reproduction produces seeds

- Describe the main functions of the reproductive structures of flowers including the anther, stigma, petals, stamen, filament, sepals, ovum, ovary, carpel and style.
- Explain the process of pollination and fertilisation in plants.

3.7

Reproduction technologies have an impact on agriculture

- Describe the purpose of selective breeding.
- Provide examples of organisms that have been selectively bred and relate selective breeding to a loss of diversity.

What if?

Dogs and roses

What you need:

A3 paper, pens

What to do:

1. Divide into small groups.
2. Divide the piece of A3 paper into two equal sections.
3. On one half, write down everything you know about how show dogs are bred.
4. On the other half, write down everything you know about how prize roses are grown.

What if?

» What if a show dog was unable to breed? What would happen to it?

» What if all rose bushes could grow identical flowers? What other factors could influence the appearance of the rose flower?

3.1 There are different ways of reproducing

Learning intentions

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

- define forms of asexual reproduction and sexual reproduction
- describe asexual and sexual reproduction in terms of genetic similarities between parent and offspring
- describe the influences of nature and nurture on the development of an individual.

Key ideas

- All living things reproduce, leaving new organisms to carry on when others die.
- Asexual reproduction involves a single organism making a copy of itself using its own genetic material.
- Sexual reproduction involves combining the genetic material from two organisms to produce a new organism.

Asexual reproduction

For some organisms, finding a partner is not easy. It takes a lot of energy and time. Some organisms can find partners easily, whereas for those that live alone or are stuck to the one spot, asexual reproduction may be their only chance of continuing the species. Asexual reproduction occurs when an organism makes young copies of itself that only contain its own genetic material.

In asexual reproduction, the offspring will often have exactly the same genetic material (known as DNA) as the parent. If an organism is really suited to an environment (they are able to survive in that temperature with that amount of water and type of food), then their identical 'children' will also be able to survive and grow.

Figure 1 The queen bee likes parthenogenesis because her unfertilised eggs always become male bees, which means no competition for her crown!

However, if the environment changes in any way that becomes unsuitable for the organism, the entire species risks extinction. The simplest version of asexual reproduction is an organism splitting in half to form two new organisms. This is known as **binary fission**.

An amazing asexual reproductive strategy known as **parthenogenesis** involves unfertilised eggs hatching into new organisms. A reticulated python in a zoo, which had been kept isolated from other snakes, managed to lay eggs that produced six daughters. The zookeepers tested the genetic material (DNA) of the baby snakes and found that it was identical to the mother's genetic material. This meant that the baby snakes were tiny identical clones of the mother. Other animals, such as some species of sea star, are able to form new individuals when they are split into two unequal parts. This is called **fragmentation**.

Fragmentation in plants is called **vegetative reproduction**. Related to the term 'vegetable' (meaning part of a plant), this refers to all non-flower parts of a plant. Vegetative reproduction generally involves a part of the plant breaking off and surviving as a new organism.

Figure 2 Plantlets are tiny plants that grow on either the parent stem, leaf or root.

Figure 3 Stolons (runners) are stems running along the ground.

Figure 4 Rhizomes are underground stems.

EXPERIMENT

3.1: Vegetative propagation
Go to page **189**.

The plant has no need for spores or seeds – a bit like fragmentation, but with structures that have been grown specifically to be broken off.

Vegetative structures include plantlets, stolons and rhizomes (Figures 2–3).

Sexual reproduction

The two cells that joined together to make you are called sex cells or **gametes** – an egg from your mother and sperm from your father. Many organisms rely on gametes fusing to make new organisms and this process is referred to as sexual reproduction. When this occurs, half the genetic material is from the mother and half the genetic material is from the father. This means each **offspring** (baby) can be different from the others.

Sometimes a female produces more than one egg. If the two or more eggs are fertilised, then non-identical twins (with different genetic material) can be produced. Occasionally, a single fertilised egg can be split into two separate cells. This produces two offspring with identical genetic material – identical twins.

Hermaphrodites

Hermaphrodites are organisms that have both male and female reproductive systems. This means they can reproduce sexually by themselves but, in most cases, it results in organisms that can change sex by 'turning off' one system and 'turning on' the other. This helps to maintain genetic diversity within the species.

Figure 5 Even though nudibranchs are hermaphrodites, they tend to find a partner to mate with. Whichever is fastest at injecting a chemical into the other will get to be the male!

Nature or nurture?

Your genetic material or DNA doesn't control how you cut your hair or what you eat, and the same goes for other organisms. Plants cannot control which leaves get eaten by predators and animals cannot control the weather. Scientists have often had lengthy discussions about 'nature versus nurture' – whether DNA is responsible for certain features or whether the features are the result of lifestyle or even upbringing. Your DNA controls your genetic features, such as the colour of your eyes or the length of your nose, whereas the environment (lifestyle, education, etc.) controls everything else and can change regularly. This means genetically identical twins can change slightly (i.e. age faster or slower) if they live in different environments (Figure 6).

Figure 6 Identical twins are only identical according to their DNA at birth.

binary fission
a form of asexual reproduction used by bacteria; the splitting of a parent cell into two equal daughter cells

parthenogenesis
asexual reproduction where a female fertilises her own eggs

fragmentation
asexual reproduction that occurs when a new organism grows from a fragment of the parent

vegetative reproduction
a type of asexual reproduction where part of a plant breaks off, forming a new organism with no need for seeds or spores; similar to fragmentation

gamete
a sex cell; in humans, the sperm and egg cells

offspring
an organism's young, or child

hermaphrodite
an organism that has both male and female reproductive systems

3.1 Check your learning

Retrieve

1 **Define** the term 'reproduction'.
2 **Identify** the substance that is responsible for most family resemblances.

Comprehend

3 **Explain** sexual reproduction and asexual reproduction.
4 **Explain** why organisms that reproduce asexually may look similar.
5 **Describe** one situation where an organism might have difficulty reproducing sexually.
6 **Describe** one situation when parthenogenesis can be useful for organisms that usually reproduce sexually.

Analyse

7 As a class, brainstorm the features of an organism that are genetically controlled (for example, in pugs used for dog breeding) and **compare** with those that are influenced by the environment (for example, wild dogs).

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

3.2 Parental care affects survival

Learning intentions

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

- define fertilisation and contrast external and internal fertilisation
- compare how r-strategists and K-strategists reproduce and explain how their environment affects their reproduction.

Key ideas

- Sexual reproduction generates more variation in offspring.
- Stable environments allow for longer parental care.
- Producing many offspring reduces the level of parental care.

fertilisation
the process where two gametes (sex cells) fuse to produce a single cell

external fertilisation
when the egg and sperm meet outside the bodies of the parents

internal fertilisation
when the sperm fertilises the egg inside the body of an organism

Sexual reproduction

Sexual reproduction occurs when two gametes combine to form a single cell. As you learnt in Topic 3.1, the two gametes come from two parents, each supplying half the genetic material. This means that half your genetic material (DNA) comes from your mother and half comes from your father. If you have siblings (a brother or a sister) half their genetic material will also come from your mother and half from your father. This does not mean that you have exactly the same genetic material as your siblings (unless you are identical twins). Each time your parents produce an egg or sperm, the genetic material is mixed. This is why siblings look different from one another. This variation between offspring is one of the key advantages of sexual reproduction. The offspring (babies) are all different from their parents, having new combinations of features. This variation is important for the survival of the entire species. If there are small variations, then some organisms are more likely to survive if the environment changes or a new disease comes along.

Asexual reproduction does not have this advantage. In all forms of asexual reproduction, offspring are genetically identical to their parent. If the parent is affected by a change in an environment, then all of their offspring will also be affected.

Sexual reproduction is the reason why many large multicellular organisms have been able to survive. **Fertilisation** is the process where the two gametes fuse to produce a single cell. This process can occur outside an organism's body (**external fertilisation**) or inside an organism's body (**internal fertilisation**).

Figure 1 Most frogs rely on external fertilisation.

External fertilisation

The process of combining gametes can occur outside the body of organisms that live in watery environments. The water allows the gametes to travel towards one another so that they can fuse. An example of this is when the male frog spreads their gametes over the eggs laid in the water by the female frog (Figure 1).

Most corals will also release their gametes into the water, relying on the current to bring the male and female gametes together so they can be fertilised (Figure 2).

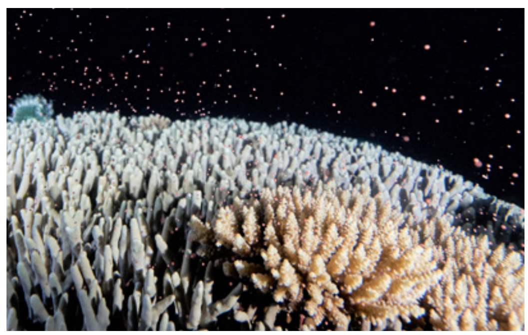


Figure 2 The corals in the Great Barrier Reef coordinate the release of their gametes to increase the chances of fertilisation.

As the gametes are released into water, there is no guarantee that fertilisation will occur. This is why external fertilisation needs many extra gametes to be produced because some will be eaten by predators or washed away before successful fertilisation can occur. Many environments on land do not have enough water for external fertilisation to occur.

Internal fertilisation

It is much more efficient for the male and female gametes to be brought together inside the body of one of the parents. This will occur in the females of most organisms. In seahorses and pipe fish, it is the father that is responsible for fertilising and caring for the offspring. Before two seahorses mate, they perform a courting dance to check that both are ready to produce offspring. The female then places their gametes in the pouch of the male seahorse. The male seahorse adds their gametes and shuts the opening of the pouch while the baby seahorses grow. Approximately 20 days later, the male seahorse will give birth to about 1000 babies at once (Figure 3).

Figure 3 The male seahorse is responsible for the internal fertilisation and birthing of offspring.

Environment affects parental care

Parenting takes a lot of time and energy in human families. This is why many human families are smaller than families in the animal kingdom. Each species can have different approaches to caring for their offspring, and this can be determined by the type of environment that they live in.

Changing environments and rapid breeding

In rapidly changing and high-risk environments, animals will usually produce a lot of offspring in the hope that some survive. These **r-strategists** rely on short periods of good conditions to quickly mate and produce high numbers of offspring. It is often unsafe for the parents to spend time with their offspring because that can attract predators. So, offspring need to be independent from birth. They grow rapidly and mature to produce their own children in a short period of time. Mice are an example of r-strategists. They will produce up to six pups every three weeks. The pups will grow to adults and be ready to reproduce in four to seven weeks. This gives the mice an advantage in a rapidly changing environment.

Stable environments and careful breeding

Animals that live in stable environments, where there is always enough food and warmth, can take more time to care for their young. These **K-strategists** usually have long pregnancies to allow the offspring to grow bigger before they are born. Newborn offspring will usually be very immature and need to rely on their parents to take care of them for more than a year. The parents can do this because they tend to only have one to two offspring at a time. The environment around them is often close to its carrying capacity (the maximum number of a species that can find food and shelter in that environment). K-strategists only need to have one to two offspring because there is a high chance that they will live to adulthood and produce offspring of their own. Humans are an example of K-strategists. We only have one to two children in each pregnancy. The children rely on their parents to survive for up to 15–20 years. Elephants, whales and eagles are all examples of animals that care for small numbers of young over a long time (Figure 4).

r-strategist
organisms living in unstable environments who breed rapidly

K-strategist
organisms living in stable environments who breed carefully

Figure 4 Humpback whales are pregnant for 11 months and give birth to a single calf that they rear for up to one year.

3.2 Check your learning

Retrieve

1 **Define** the term 'fertilisation'.

2 **Explain** why animals that use external fertilisation usually lay a large number of eggs.

Comprehend

3 **Describe** why it is an advantage for all coral to release their gametes at the same time each year.

4 **Explain** why you may look different from your sibling.

5 **Explain** why sexual reproduction produces variation.

6 **Explain** why variation is important to survival.

Analyse

7 **Contrast** internal and external fertilisation.

8 **Compare** the way r-strategists and K-strategists reproduce.

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

3.3 The female reproductive system produces eggs in the ovaries

Learning intentions

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

- describe the main structures and functions of the female reproductive system
- explain the main processes involved in the menstrual cycle.

Key ideas

- The female reproductive system varies between vertebrates depending on the reproductive habits of the species.
- Human females have a large uterus, two fallopian tubes and two ovaries.
- Each month an ovary produces one ovum during ovulation.
- Some animals (rats and rabbits) have a uterus large enough for multiple fetuses.
- Amphibians lay their eggs in water.

Human reproduction

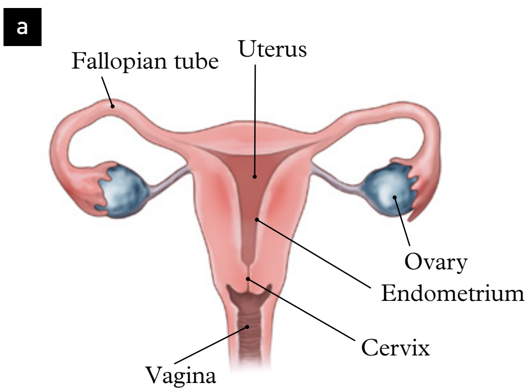
In humans, girls are born with hundreds of thousands of eggs or ova (singular '**ovum**') partially formed in their **ovaries**. After puberty, every month a hormone from the brain sends a message to the ovaries to secrete a second hormone called **oestrogen**, which causes one egg to mature and be released. This process is called **ovulation**.

The egg travels down the **fallopian tubes** to the **uterus**. If sperm are present in the fallopian tubes, then the egg may become fertilised. In the three to five days it takes for the egg to travel the fallopian tubes, the lining of the uterus (the **endometrium**) becomes thicker. This is to provide a safe place for the fertilised egg, or **zygote**, to grow into a **fetus** (Figure 2).

If the egg is not fertilised, then the endometrial lining will break down and, two weeks after ovulation, will pass through the **cervix** and **vagina** as a period. This monthly cycle is called **menstruation**.

Menstruation usually first occurs in females between 8 and 16 years of age. It can take up to two years for menstruation to become a regular cycle. The average length of the cycle is 28 days, but it can vary from 23 to 35 days (Figures 3 and 4).

If the egg is fertilised in the first three days after ovulation and develops into a zygote, then it attaches to the thick endometrial layer. A special organ called the **placenta** forms between the fetus and the uterus. The placenta allows oxygen and nutrients to pass from the mother to the developing fetus. The length of time between fertilisation and birth is called **gestation** (or pregnancy). In humans, gestation takes nine months.



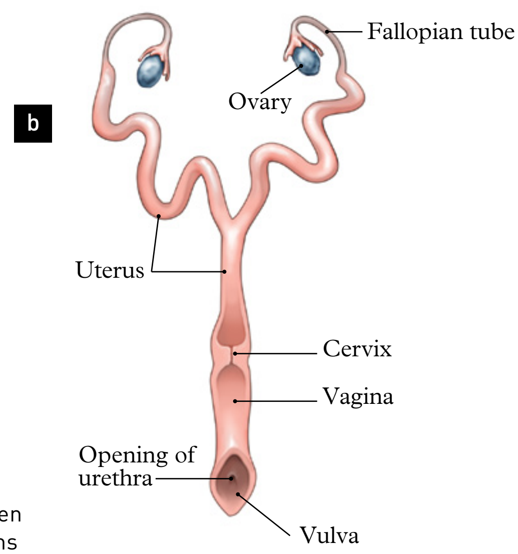


Figure 1 The female reproductive system varies between vertebrates. **a** Human and **b** rabbit reproductive systems

ovum
the reproductive egg

ovary
the female organ that produces eggs

oestrogen
a reproductive hormone in females

ovulation
the part of the menstrual cycle when an egg is released from the ovary

fallopian tubes
tubes that connect the ovaries to the uterus

uterus
an organ in the female reproductive system; where the fetus develops

endometrium
the lining of the uterus

zygote
a fertilised egg

fetus
an unborn animal or human after the embryo stage; in humans this is after 8 weeks of development

cervix
the narrow neck connecting the uterus and the vagina

Figure 2 A human fetus

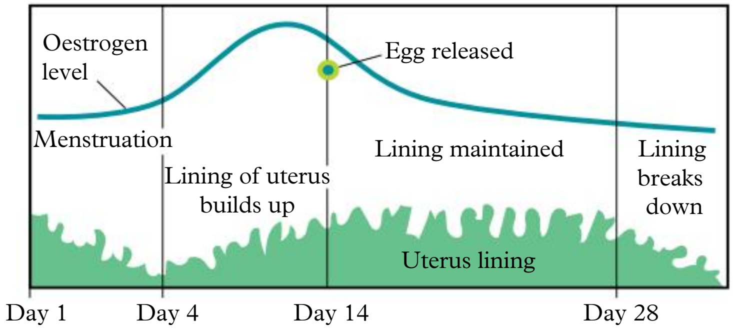


Figure 3 During the average 28-day menstrual cycle, ovulation occurs at day 14.

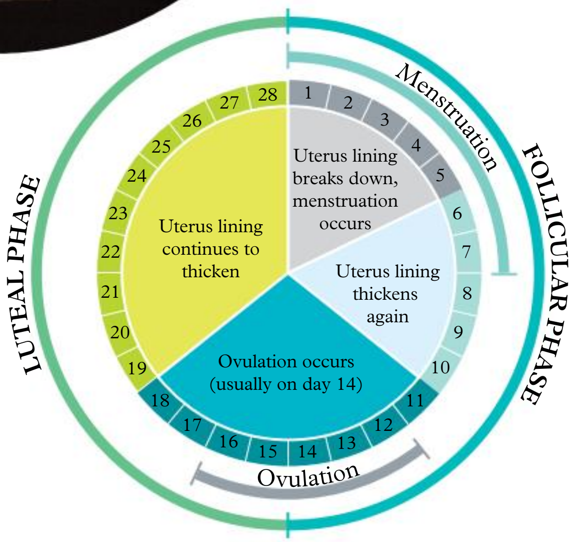


Figure 4 The menstrual cycle begins on the first day of a period.

Giving birth

Human mothers go through three stages when giving birth (Figure 5). The first stage involves the muscular walls of the uterus contracting, gently squeezing the baby down against the cervix. This causes the cervix to flatten and start dilating (opening). The cervix must open 10 cm before the baby's head can move through the vagina. This is the second stage of birth. When born, the baby is still attached to the placenta, which is inside the mother, via the umbilical cord. When the umbilical cord is cut, it will form the baby's belly button. The third and final stage of birth is the delivery of the placenta. This is important to prevent infections from developing in the uterus.

vagina
a female reproductive organ; a muscular tube connecting the outside of the female body to the cervix

menstruation
also know as a period; the process of the endometrial lining of the uterus breaking down and leaving the vagina

placenta
the organ that connects the developing fetus to its mother

gestation
the length of time between fertilisation and birth

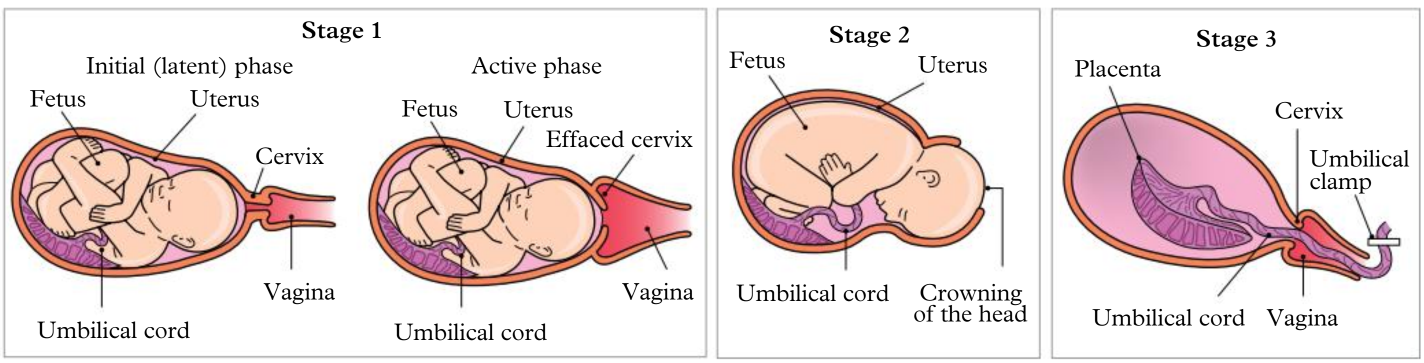


Figure 5 The three stages of childbirth

3.3 Check your learning

Retrieve

1. **Recall** one hormone involved in reproduction in human females.
2. **Identify** where in the reproductive system the ovum becomes fertilised in humans.
3. **Define** the term 'menstruation'.
4. **Identify** the days (1, 2, 3 ...) in the average menstrual cycle when the following occur.
   a. the first day of a period
   b. the usual day of ovulation
   c. when the ovum can be fertilised
5. **Recall** how often menstruation usually occurs.

Comprehend

6. **Describe** the three stages of giving birth.

Apply

7. A student said that a baby girl already had all her eggs intact when she was born. **Evaluate** this claim (by describing where all the eggs/ova are located, describing when this organ is fully formed and deciding whether the statement is correct).

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

3.4 The male reproductive system produces sperm in the testes

Learning intentions

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

- define sexually dimorphic, testosterone and oviduct
- describe the main structures and functions of the male reproductive system.

Key ideas

- Male mammals produce sperm in their testes.
- Sperm will mature in the epididymis, travel along the vas deferens where the seminal vesicles provide nutrients before being ejaculated from the penis.

The vast majority of animals reproduce sexually. They are also **sexually dimorphic**, which means that the males look physically different from the females.

Male reproductive organs

In fertilisation, a gamete from the father (sperm) must meet a gamete from the mother (egg or ovum). The sperm is produced in special organs called the **testes**. The testes are also responsible for producing a male hormone called **testosterone**. In most mammals, the two testes are kept outside the body in a sack called the **scrotum**. This is to keep the sperm cooler than the 37°C of the rest of the body. If sperm get too hot they will not be able to fertilise an egg properly.

Once sperm are produced in the testes, they move to the **epididymis** to mature. When necessary, the epididymis contracts (squeezes tight), and the sperm is moved into the **vas deferens**. The sperm need energy to be activated. **Seminal vesicles** are small pouch-like structures that provide a sugary fluid that is needed for the sperm's journey along the vas deferens tube to the **prostate gland**. The prostate gland is a walnut-sized structure that blocks the flow of urine so that the sperm can move along the urethra and be ejaculated out through the penis. The function of the penis is to help the sperm reach the eggs. Sperm can survive up to five days after ejaculation.

Fertilisation

Mammals, such as humans, use internal fertilisation and the mother is responsible for nurturing the growing fetus in the uterus until it is ready to face the world. Placental mammals, like humans, keep the fetus in the uterus for this period of gestation, whereas marsupial fetuses such as those of the koala, crawl into the pouch for the final stages of development.

Monotremes, a very rare group of mammals that consists of the platypus and the echidna, lay leathery eggs.

All female mammals suckle their young with highly nutritious milk to give their offspring the best start in life.

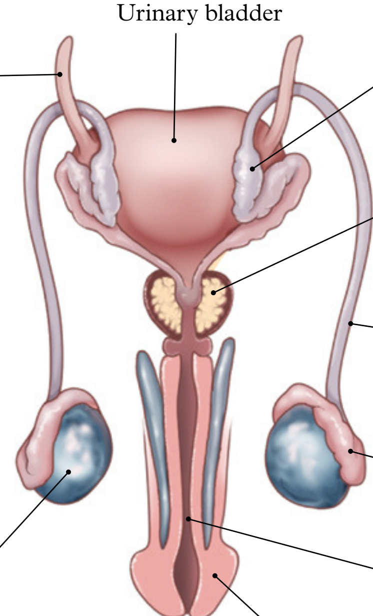


Figure 1 Human male reproductive system

sexually dimorphic
describes species in which the male and female organisms look structurally different

testis
the male reproductive organ that produces sperm (plural: testes)

testosterone
a male hormone involved in the reproductive system

scrotum
a sac-like structure that contains the testes

epididymis
a coiled tube behind the testes that carries sperm to the vas deferens

vas deferens
the tube through which sperm travel from the epididymis to the prostate

seminal vesicles
a pair of small pouch-like structures that provide a sugary fluid that assists sperm to travel along the vas deferens

prostate gland
a walnut-sized structure surrounding the neck of the male bladder that blocks the flow of urine so sperm can move along the urethra

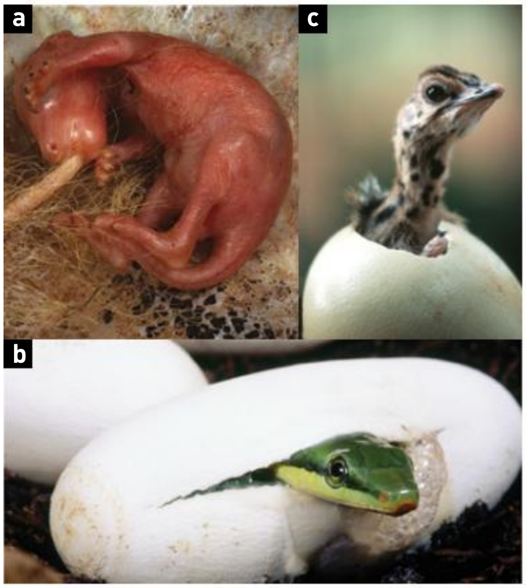


Figure 2 a Marsupial fetuses finish developing in the pouch. **b** Reptile eggs are leathery white. **c** Birds' eggs are hard.

Like monotremes, reptiles and birds lay internally fertilised eggs. Reptile eggs are leathery, whereas bird eggs have a hard shell. The eggs contain all the nutrients that the fetus needs to develop fully, which is important for reptiles because most of them leave their babies to fend for themselves.

Amphibians and fish generally practise external fertilisation. This usually involves the female laying the eggs in the water and the male coating them with sperm. Often hundreds of eggs are laid at once so there's a greater chance some will survive – they make a tasty snack for passing predators! Some parents will keep watch to ward off predators.

Invertebrates making babies

Invertebrates account for approximately 95 per cent of all animals, so it's not surprising that their reproductive strategies vary quite a lot.

Arthropods, the group that includes insects, spiders and crustaceans, is the largest group of invertebrates.

Terrestrial (land) arthropods generally favour internal fertilisation because of the harsh conditions they often live in. Sometimes the sperm is transferred directly into the female's **oviduct** (fallopian tube in humans) and sometimes the sperm is packaged for delivery to the female in more complex ways. Most arthropods then lay their eggs. Insects and crustaceans tend to hatch as larvae. Spiders hatch as miniature adults.

Figure 3 Some fish protect their eggs from predators.

oviduct
the tube through which eggs travel from the ovary

Figure 4 A female fly lays eggs through her oviduct.

3.4 Check your learning

Retrieve

1 **Define** 'sexual dimorphism' in your own words.

2 **Name** a hormone involved in male reproduction.

3 **Identify** the two vertebrate classes that lay leathery eggs.

Comprehend

4 **Identify** the group of mammals that has the longest gestation. **Explain** why this would be an advantage for the baby.

5 **Explain** why terrestrial invertebrates fertilise their eggs internally rather than externally.

Apply

6 If an ovum is produced on day 14 of a menstrual cycle, and sperm can survive up to five days before fertilisation, **determine** the days of a cycle that a woman can become pregnant.

7 **Create** a story that describes the journey of Mr Sperm from his home in the testes to meet the love of his life, Ms Ovum.

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

//SCIENCE AS A HUMAN ENDEAVOUR//

3.5 Sometimes things go wrong with reproduction

Learning intentions

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

- define contraception, inbreeding and desexing
- describe some common problems of the human reproductive systems.

There are many situations in which we wish to encourage reproduction. For example, when a human couple are unable to have a baby, technology can intervene. When a species is threatened with extinction, technology can reduce the threat; and when certain features or characteristics are favoured, humans step in to influence the outcome. Likewise, when reproduction is not desirable, something can be done to prevent it.

Endometriosis

Sometimes the lining of the uterus, the endometrium, starts growing outside the uterus. These cells can grow on the outside of the uterus or spread to other organs, such as the ovaries. Each month these endometrial cells grow, and then break down, just as in the menstrual cycle. This can be very painful; it can cause vomiting or prevent a woman from doing her normal activities. Also, the scarring that results can prevent the eggs from moving down the fallopian tubes. This can make it difficult for pregnancy to occur. Anyone who suffers from endometriosis should see their doctor so that it can be treated.

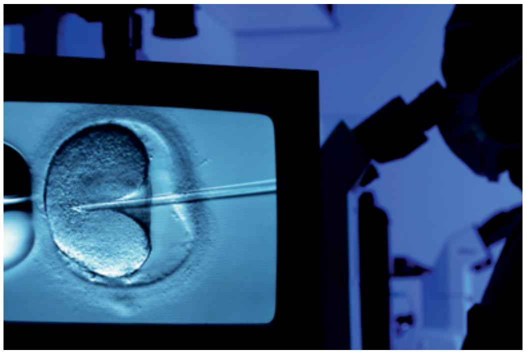


Figure 1 In IVF, eggs are injected with sperm for fertilisation.

Human reproduction

Assisted reproductive technology (ART) is the name given to any procedure that is used to help a couple have a healthy baby. Through in vitro fertilisation (IVF) an egg is fertilised by sperm *in vitro* or 'in glass', meaning in a test tube. This is done so that a doctor can carefully watch every step to make sure that the egg gets fertilised and begins dividing as it is supposed to. Australia has even trained artificial intelligence to identify if a fertilised egg can successfully grow into an embryo. The tiny embryo can then be transferred back into the mother's uterus to go through a normal pregnancy.

Unborn babies can be screened for problems. The amniotic fluid that protects the growing fetus can be tested (amniocentesis), as can the cells of the placenta (chorionic villus sampling). The problem with these tests is that they involve inserting a needle into the belly, which may result in an infection or may interfere with the pregnancy, risking more problems than can be diagnosed. Thankfully, many issues can be spotted in an ultrasound – a picture of what is going on inside, complete with heartbeats.

Preserving biodiversity

Humans rely on the diverse range of living things (biodiversity) for food, transport, tourism and even inspiration, so it is important that we try to stop species becoming extinct.

Many scientists work out in the wild to try to help different organisms, but the most intensive programs are often happening in our zoos and sanctuaries. These are called captive breeding programs.

CHALLENGE

3.5: Working with the RSPCA
Go to page 190.

Figure 2 Captive breeding programs are helping to save the bilby.

When an animal is in a zoo, specialists of all types can observe and help the animal to breed. They might try to make the environment ideal by changing the temperature or providing the right nutrients. They can also bring animals together at just the right time, or even try animal IVF.

Contraception and desexing

It may sound silly, but many animals in captivity are on some form of **contraception** to stop them getting pregnant. This may be to control **inbreeding** or simply because there's not enough room or resources for more animals in the facility.

Desexing is a permanent contraceptive strategy that involves either the male or the female having their vas deferens or fallopian tubes 'tied', or blocked, or removed altogether.

Local councils commonly require animals that are pets to be desexed. Cats, for example, often wander freely during the day and have many opportunities to breed – but who will look after all the kittens? If everyone's cats were free to breed, the neighbourhood would soon be swarming with kittens or wild cats hunting all the local wildlife.

Figure 3 Ultrasounds allow the developing fetus to be seen.

Figure 4 It's not a very happy life for domestic animals without food or shelter.

contraception
a way of preventing pregnancy

inbreeding
breeding of animals that are related, increasing the chances of genetic abnormalities appearing

desexing
a method of permanently preventing reproduction

3.5 Test your skills and capabilities

Analysing and evaluating a zoo

Many people argue that it is inhumane to keep animals in a zoo. They claim that the animals are kept from their normal habitat for the enjoyment of humans. Use critical thinking to decide whether you support your local zoo. To do this, complete the following tasks.

1 **Define** the term 'inhumane'.
2 **Consider** how the animals usually live in their normal habitat. Select one animal as an example.
   a **Research** the plants, temperature and shelter that the animal has in their habitat in the wild.
   b **Research** the types of food that your chosen animal eats.
   c **Research** the usual habits of your chosen animal (i.e. how far they move, what they do each day, whether they live in groups).
3 **Compare** your research to how the animals live in the zoo.
4 **Identify** how endangered your animal is in their usual habitat and if the zoo is involved in any breeding programs. **Describe** the breeding program.
5 **Explain** why you do or do not support your local zoo.

3.6 Plant sexual reproduction produces seeds

Learning intentions

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

- describe the main functions of the reproductive structures of flowers including the anther, stigma, petals, stamen, filament, sepals, ovum, ovary, carpel and style
- explain the process of pollination and fertilisation in plants.

Video 3.6A Flower dissection

Video 3.6B Flowering plants

Key ideas

- Flowers help plants to use sexual reproduction.
- When the male plant gamete lands on the female plant gamete, pollination has occurred.
- Plants can self-pollinate or be cross-pollinated by another plant.
- Insects or birds can help pollinate plants.

Flowers come in all shapes and sizes. Not all of them are attractive and many smell terrible instead of lovely. However, the purpose of a flower is not necessarily to be sweet-smelling and beautiful, but to contain the sexual reproductive organs of the plant and to help fertilisation to occur.

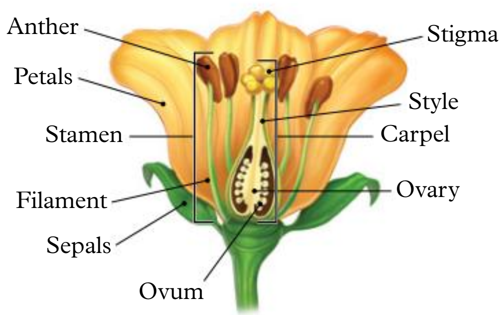


Figure 1 Basic structure of a flower

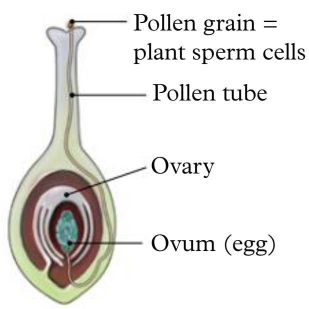


Figure 2 Structure of the carpel with key structures labelled

Pollination

The female gamete, also called an ovum, is located at the base of the **stamen** inside the ovary. All these female parts together are called the **carpel**. For fertilisation to occur, the male gamete needs to find its way from the top of the male structure, the **anther**, to the ovum.

This requires **pollination**, the process of pollen attaching to the **stigma** and 'digging' a pollen tube down to the ovary.

Flowers sometimes need assistance from other organisms (insects, birds or mammals) or the environment (wind or rain) for pollination to occur. **Self-pollination** involves pollen from a flower landing on its own stigma or that of another flower on the same plant (Figure 2). **Cross-pollination** occurs when pollen from a flower lands on the stigma of a flower on a different plant, combining two different sets of genetic material (Figure 3). Just as in animals, the pollen from one flower can only fertilise flowers from the same or a similar species.

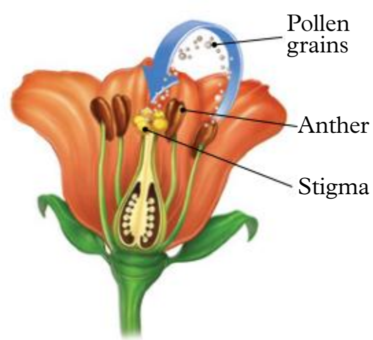


Figure 3 Self-pollination occurs when the pollen grain and ova come from the same plant.

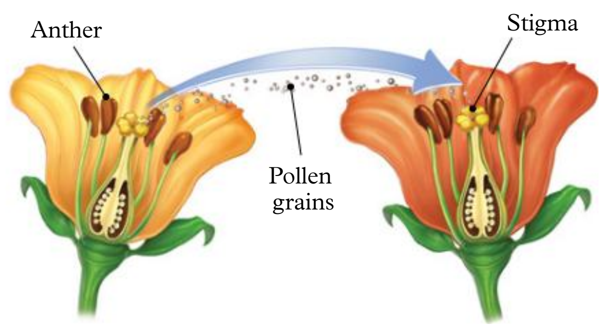


Figure 4 Cross-pollination occurs when the pollen grain and ova come from different plants.

stamen
the male part of a plant, consisting of a filament supporting an anther

carpel
the female reproductive organ of a flower; includes the stigma, style and ovary

anther
the end part of a stamen (male part of a flower); contains pollen

pollination
fertilisation of gametes in plants

stigma
the top of the carpel; where the pollen from the anther begins its journey to the ovary

EXPERIMENT

3.6: Flower dissection
Go to page **191**.

After fertilisation, the ovary takes on a role similar to that of a bird's egg. It swells to become a fruit, which provides nutrition and protection for the zygotes to grow into embryos inside the seeds. The ovary structure is seen in the structure of the seed-bearing area of the fruit, as shown in Figure 1.

Some flowers have modified structures to suit their pollinators. Birds may damage flowers with their sharp beaks when they drink the nectar, so flowers need to be strong. Insects can be small and need to be forced to brush against pollen, followed by the stigma, so the flower may be full of obstacles or simply a tight fit.

Not all flowers are the same

If a flower smells, it is usually to attract a pollinator – but not all smells are sweet. The flowers of Borneo's Rafflesia plant smell like rotting flesh to attract flies for pollination!

The colour of a flower is also important for attracting pollinators. Birds tend to pollinate brightly coloured flowers, including red, whereas insects may be more attracted to a wide range of colours. Mammals that feed at night will rely on strong scents and not on colour at all.

Figure 5 When in bloom, the Rafflesia smells like rotten meat to attract pollinating flies.

Sexual spores

If you've ever had a good look at a fern you will have noticed that its leaves are usually quite different from the leaves of flowering plants. You will often see brown patches on the underside of fern fronds. These brown patches are specialised cells that make and release **spores** onto the ground. The spores are tiny reproductive structures that have half the genetic material of seeds. They grow into tiny heart-shaped plants called prothalli that are made up of male and female reproductive organs. Male and female gametes are produced and released when it rains – hopefully, to find a match for fertilisation. The little plant then dies, but the fertilised eggs grow into new ferns.

Figure 6 Fern sori (the brown patches) produce spores for reproduction.

self-pollination
when both gametes come from the same plant

cross-pollination
the exchange of pollen and ova between different plants of the same species

spore
a tiny reproductive structure that, unlike a gamete, does not need to fuse with another cell to form a new organism

3.6 Check your learning

Retrieve

1 **Identify** the structure that holds a plant's sexual reproductive systems.

Comprehend

2 **Explain** why some flowers are large and coloured, and others are tiny and plain.

Analyse

3 **Contrast** self-pollination and cross-pollination.

4 **Compare** fertilisation and pollination.

5 **Compare** a spore with a seed.

Apply

6 Plants that are successful weeds often use both sexual and asexual reproduction. Mint is common in herb gardens and reproduces with little flowers as well as using vegetative reproduction. **Discuss** why it would be difficult to get rid of mint once it has spread through a garden bed.

7 **Create** a circular flow diagram using the following terms: flower, pollen, seed, fruit, pollination, fertilisation, ovum, pollen, ovary, stigma and anther.

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

3.7 Reproduction technologies have an impact on agriculture

Learning intentions

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

- describe the purpose of selective breeding
- provide examples of organisms that have been selectively bred and relate selective breeding to a loss of diversity.

Key ideas

- Reproductive technologies can be used in agriculture to improve desired characteristics in plants and animals.
- Reproductive technologies can have an impact on diversity and increase the risk of inbreeding.

Selective breeding

There are many examples of animals and plants being bred to keep, lose or enhance certain characteristics by people choosing the breeding 'partners'. For example, a cow that is known to produce a lot of milk could be chosen to breed with a bull that is known to produce healthy, strong offspring. This would result in a greater chance of any female offspring being good milk producers and any male offspring being good meat producers.

Occasionally, animals have difficulty in breeding. This may be due to location (the animals may be on opposite sides of the country) or their owners wanting to have greater control over the animals they breed with. As a result, sperm banks for animals have been developed. Desired characteristics, such as speed or 'staying power' in racehorses, or facial shape or coat colour in dogs, are described in a catalogue for owners to examine. The desired frozen sperm can be purchased and sent to the owner of the female animal, where it will be used to create offspring with the desired characteristics.

Selective breeding also applies to plants. A type of wheat that is known to survive frost or disease can be deliberately cross-pollinated with a type of wheat that produces high-quality grains; the aim of this is to produce a grain that combines both features.

Loss of diversity

Diversity in plants and animals refers to the variety of genetic material in a single population or species. When a characteristic, such as milk production in cows, is used for selective breeding, any cow that does not produce 'enough' milk is discouraged from breeding. This often means the genetic material from that cow is not passed on to the next generation. Instead, the next generation of calves will only have genetic material from the few cows that meet the milk production criteria.

Figure 1 Some people get a little carried away with selective breeding.

As a result, most of the cows can be related to one another and there is less variation in the genetic material. Although this does not seem like a problem initially, it puts the whole population at risk of disease. If one plant or animal is at risk of a disease, then the rest of that related population, with the same genetic material, is also vulnerable.

An example of this is facial tumour disease in the Tasmanian devil. All Tasmanian devils have very similar genetic material. When one individual devil developed a tumour on its face, it was able to pass it on to another devil that had similar genetics.

Figure 3 Tasmanian devil facial tumour disease is caused by the uncontrolled growth of cancerous cells. The cancerous cells are passed between devils when they bite one another.

Figure 2 In the mid-1800s, the population of Ireland relied very heavily on potatoes for food. When a fungus infected the potatoes, the lack of genetic diversity meant that all potato crops were wiped out and about 1 million people died of starvation.

Inbreeding

Inbreeding results from animals reproducing with animals to which they're closely related. When this happens, rare diseases can show up. For example, some dogs that were chosen to breed because of their particular looks may also have hip problems. Inbreeding has been quite a problem with dog breeds, especially when people don't check an animal's ancestry carefully.

Figure 4 Labradors are known to have hip problems as the result of many years of inbreeding.

3.7 Check your learning

Retrieve

1 **Define** the term 'selective breeding'. Give one example in your answer.

Comprehend

2 **Describe** the technology that can be used to assist selective breeding.

3 **Describe** an example of how inbreeding could occur.

4 **Explain** why genetic diversity in a population is important.

5 **Explain** why selective breeding is not always a good idea.

Apply

6 **Investigate** an example of the difficulties faced by breeding flat-faced pug dogs.

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

Figure 5 A healthy wheat crop

CHAPTER 3 REVIEW

REPRODUCTION

Retrieve

1 **Identify** what type of reproduction occurs when a bacterial cell divides in two equal parts.
- A cross-pollination
- B parthenogenesis
- C fragmentation
- D binary fission

Figure 1 A cell dividing in two equal parts

2 **Identify** the term used to describe the pollen from one flower being carried to another plant.
- A cross-pollination
- B parthenogenesis
- C fragmentation
- D asexual reproduction

3 **Identify** the reproductive term used to describe rapid reproduction of many offspring in a changing environment.
- A internal fertilisation
- B external fertilisation
- C r-strategist
- D K-strategist

4 **Identify** the scientific term used for 'making new organisms'.

5 **Define** the term 'gamete'.

6 **Identify** the common names for the two gametes in animals. **Identify** the common names for the two gametes in plants.

7 **Recall** which produces greater variation: sexual or asexual reproduction.

8 **Recall** an example of each of the following types of asexual reproduction.
- a parthenogenesis
- b fragmentation
- c vegetative reproduction

9 **Define** the term 'sexually dimorphic' and identify a sexually dimorphic species.

10 **Complete** Figure 2 by **identifying** the missing labels for parts of the flower's reproductive structure.

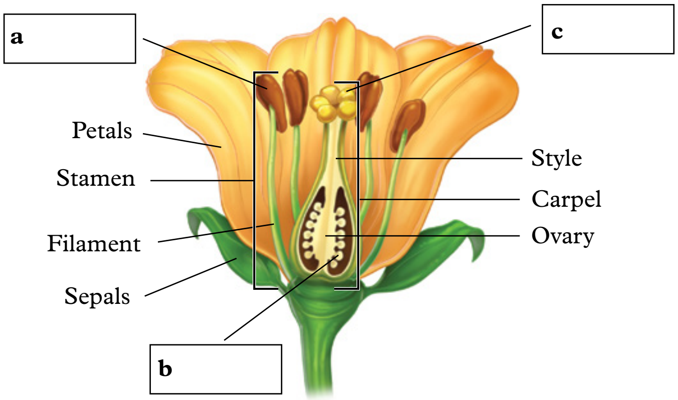


Figure 2 Structure of a flower

Comprehend

11 **Describe** the function of a fruit in reproduction.

12 **Describe** why organisms that fertilise internally tend to produce fewer eggs than those that fertilise externally.

13 **Describe** how reproduction strategies may change in stable or changing environments.

14 **Explain** the processes involved in the menstrual cycle.

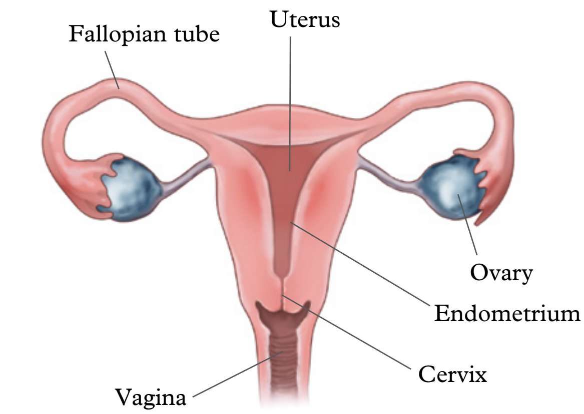


Figure 3 The female reproductive system

15 **Explain** why a hermaphrodite reproducing alone would be considered asexual reproduction.

16 Skinks (a type of lizard) drop their tails when threatened, but their tails can grow back. **Explain** why this is this not a type of asexual reproduction.

Analyse

17 A 13-year-old girl was keeping a record of her menstrual cycle. She found her cycle lasted approximately 28 days. If her last period started on 1 June, **identify** the following:

a when she should ovulate

b when her next period should start.

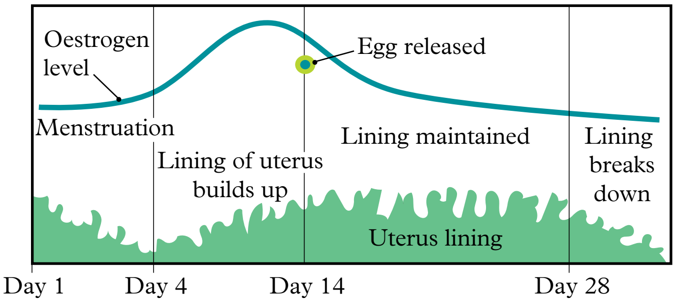


Figure 4 The average 28-day menstrual cycle

18 Examine the images in Figure 5. **Identify** two features that are genetic and two that are environmental.

Figure 5 These dogs are from the same litter.

19 **Contrast** a fetus and a baby.

20 **Contrast** a spore and a seed.

Apply

21 Some reptile eggs are affected by the temperatures they experience while incubating in the nest (Figure 6). For example, within a single nest, high temperatures will produce female turtles while lower temperatures will produce male turtles. Most nests produce a mixture of turtle sexes. **Discuss** how warmer weather as a result of the enhanced greenhouse effect might impact green sea turtle populations.

Figure 6 Green sea turtle eggs produce female babies when the eggs are warmer and male babies when the eggs are cooler.

22 Use your knowledge of plant reproduction to design a new flower. **Describe** how your flower will reproduce (wind, water, insects or birds). **Create** a picture of your new flower. Label the stamen (with filament and anther), the carpel (with stigma, style and ovary) and the petals of the flower.

23 **Identify** which is better for maintaining biodiversity: self-pollination or cross-pollination. **Justify** your answer (by defining each term, providing an example of the consequences of each process and deciding which will provide the greatest biodiversity).

24 A farmer grows two types of corn on the farm. One type is affected by the frosts in winter but produces really large, juicy corn cobs when it is protected. The other copes in winter without a problem but has only small corn cobs. **Propose** one way the farmer could improve their crops.

Social and ethical thinking

25 When people are deciding if they agree or disagree on a social or ethical issue, they will often base it on their personal experiences. **Discuss** what you know about in vitro fertilisation (IVF) techniques. **Identify** where you learnt this information. **Identify** reasons why some people may want to use IVF. **Identify** two reasons why some people may not want to use IVF.

26 Divide into two groups to **investigate** and debate one of the topics below.

a Selective breeding is essential to maintain food production for humans.

b Reproductive technologies interfere with nature.

c Selective breeding is important in preventing extinction.

d Genetic diversity can be maintained without technology.

Critical and creative thinking

27 Humans don't reproduce asexually – ever. **Predict** the possible consequences that might occur if a single human was able to reproduce asexually. **Predict** the possible consequences that might occur if many humans were able to reproduce asexually.

28 The life cycles and reproductive strategies of invertebrates are incredibly diverse. Choose an invertebrate to **investigate** and present your findings to the class in the form of a poster or webpage. **Investigate** projects that could be shared in a mini-conference format.

Research

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

» Chorionic villi sampling (CVS)

Chorionic villi sampling is a procedure that some pregnant mothers undergo to test for genetic problems in the developing fetus.

- » Describe how this procedure is performed.
- » Describe when this test is usually taken.
- » Describe the type of abnormalities that can be detected with this test.
- » Identify an ethical issue that may arise as a result of this test.
- » Describe what genetic counselling is.

» Seed banks

A seed bank stores a large variety of seeds in case a particular species of plant is placed at risk as a result of natural disaster or outbreaks of disease or war.

- » Research a major seed bank near your school.
- » Describe the types of seeds they collect.
- » Identify who collects the seeds for the bank.
- » Describe how the seeds are collected.
- » Describe the conditions that are needed for the seeds to remain viable (alive).

Figure 7 Seed banks store different plant seeds to protect species from endangerment or extinction.

» Dog breeding in Australia

Some breeds of dogs are vulnerable to genetic problems, such as difficulty breathing or displaced hips, as a result of decades of inbreeding.

- » Research a breed of dog that has such difficulties.
- » Describe the features that these pedigree dogs are judged on in dog shows.
- » Describe the problems that have arisen as a result of the inbreeding.
- » Describe the measures that the RSPCA and the Australian National Kennel Council are taking to ensure these problems do not continue.

Figure 8 Pugs are one breed of dog that is vulnerable to genetic problems.

» Contraception

Contraception is the term used for the range of methods and devices that are used to prevent pregnancy. Contraception has been used for thousands of years.

- » Contrast barrier, surgical and chemical methods of contraception.
- » Research two methods of contraception that can be used by humans.
- » Identify whether males or females use these methods.
- » Describe how effective each of these methods are at preventing pregnancy.

Chapter checklist

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

	I can do this.	I cannot do this yet.
• Define forms of asexual reproduction and sexual reproduction. • Describe asexual and sexual reproduction in terms of genetic similarities between parent and offspring. • Describe the influences of nature and nurture on the development of an individual.	☐	☐ Go back to Topic 3.1 'There are different ways of reproducing'. Page 58
• Define fertilisation and contrast external and internal fertilisation. • Compare how r-strategists and K-strategists reproduce and explain how their environment affects their reproduction.	☐	☐ Go back to Topic 3.2 'Parental care affects survival'. Page 60
• Describe the main structures and functions of the female reproductive system. • Explain the main processes involved in the menstrual cycle.	☐	☐ Go back to Topic 3.3 'The female reproductive system produces eggs in the ovaries'. Page 62
• Define sexually dimorphic, testosterone and oviduct. • Describe the main structures and functions of the male reproductive system.	☐	☐ Go back to Topic 3.4 'The male reproductive system produces sperm in the testes'. Page 64
• Define contraception, inbreeding and desexing. • Describe some common problems of the human reproductive systems.	☐	☐ Go back to Topic 3.5 'Science as a human endeavour: Sometimes things go wrong with reproduction'. Page 66
• Describe the main functions of the reproductive structures of flowers including the anther, stigma, petals, stamen, filament, sepals, ovum, ovary, carpel and style. • Explain the process of pollination and fertilisation in plants.	☐	☐ Go back to Topic 3.6 'Plant sexual reproduction produces seeds'. Page 68
• Describe the purpose of selective breeding. • Provide examples of organisms that have been selectively bred and relate selective breeding to a loss of diversity.	☐	☐ Go back to Topic 3.7 'Reproduction technologies have an impact on agriculture'. Page 70

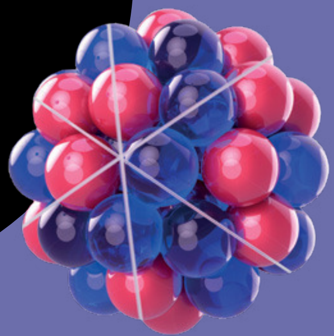
Check your Student obook pro for these digital resources and more:

Quizlet
Play a Quizlet game to test your knowledge.

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

CHAPTER

4



SUBATOMIC PARTICLES

4.1

Atoms are made up of subatomic particles

> Define atomic theory, electron, Thomson plum pudding model, nucleus, proton and neutron.

> Describe the Rutherford model of an atom.

4.2

Atoms have mass

> Describe how the elements are ordered on the periodic table.

> Explain the difference between atomic number and mass number.

4.3

Isotopes have more or less neutrons

> Define isotope and relative atomic mass.

> Compare the structure of isotopes of the same element.

> Explain how the relative mass of an element is calculated.

4.4

Isotopes can release alpha, beta or gamma radiation

> Define radioactive decay, radionuclide, alpha radiation, beta radiation and gamma radiation.

> Describe the relationship between a half-life and the number of atoms of a substance.

4.5

The half-life of isotopes can be used to tell the time

> Describe how the half-life of a radioisotope can be used to tell the time.

> Explain how carbon dating works.

4.6

Science as a human endeavour: Radiation is used in medicine

> Describe the effects of radiation on the human body.

> Provide examples of the use of radiation in medicine.

What if?

Aluminum atoms

What you need:

Strip of aluminium foil, scissors, microscope

What to do:

1 Each piece of aluminium foil contains atoms of aluminium. Use the scissors to cut your piece of aluminium in half.

2 Cut one of the pieces in half again.

3 Repeat step 2 until your piece of aluminium is too small to cut.

4 Examine the piece of aluminium using the microscope.

What if?

» What if you were able to continue to cut the piece of aluminium until just one atom remained? (Could you see it under the microscope?)

» What if you could see inside the aluminium atom? (What would you see?)

4.1 Atoms are made up of subatomic particles

Learning intentions

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

- define atomic theory, electron, Thomson plum pudding model, nucleus, proton and neutron
- describe the Rutherford model of an atom.

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

subatomic particle
a particle that is smaller than an atom

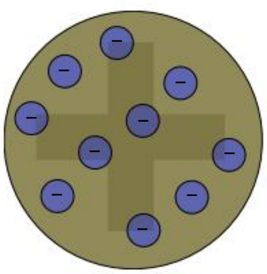


Figure 1 Thomson's plum pudding model of the atom

Key ideas

- The Rutherford model of atoms suggests that an atom has a central nucleus containing positively charged protons, and neutrons with no charge.
- Negatively charged electrons travel around the space outside the atom's nucleus.
- Atoms have no overall charge.

In 1810, English scientist John Dalton stated:

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

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

This theory gave scientists a way to explain the evidence about atoms, and it is now supported by a range of new evidence. Ever since Dalton first proposed his atomic theory, it has been used to make predictions.

Discovering more about atoms

A century after Dalton proposed his theory, in the early twentieth century, the physicist Joseph John Thomson discovered that atoms were actually divisible and were made up of even smaller **subatomic particles** (particles that are smaller than atoms). His experiments showed that inside the atom are far smaller, negatively charged particles, which we now call **electrons**.

He also showed that an atom contains positively charged material, although it was not yet clear what this material was. From this discovery, and knowing that oppositely charged objects attract each other and move towards each other, Thomson suggested that the atom is like a plum pudding, in which the positively charged material is the 'cake' and the electrons are the fruit. The positive and negative charges are mixed uniformly througout the atom in what was called the **Thomson plum pudding model** of the atom (Figure 1).

Rutherford's experiments on atoms

Ernest Rutherford was born in New Zealand in 1871. His experiments changed the way people thought about the inside of the atom. In 1911, he supervised Hans Geiger and Ernest Marsden, who carried out what is known as the 'gold foil' experiment (Figure 2). They set up a very thin layer of gold foil and fired a stream of alpha particles at it. Alpha particles are very small, positively charged radioactive particles that contain energy. Detectors were set up around the gold foil to record the path of the radioactive particles. This would identify whether the particles had gone straight through the foil or had been deflected (made to change course) by the gold atoms in the sheet of gold foil. If the plum pudding model was correct (that the positive and negative charges were distributed uniformly throughout the atom), then the alpha particles should shoot straight through the neutral (no charge) gold foil by passing through the gaps between the gold atoms (Figure 3).

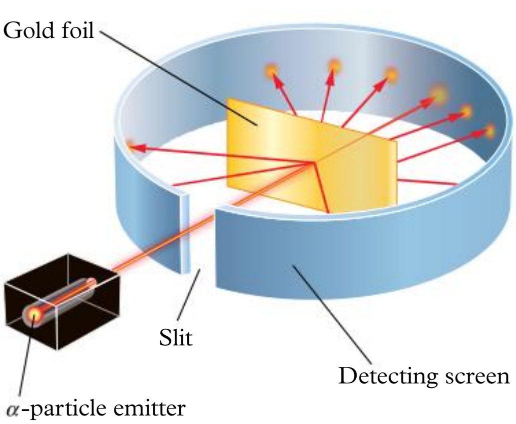


Figure 2 Rutherford's gold foil experiment. Note the large deflection of some particles.

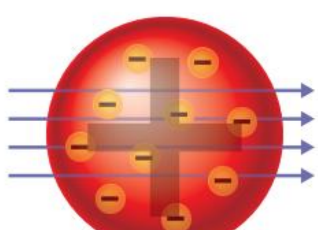


Figure 3 If the 'plum pudding' model of the atom were correct, it would be expected that most of the alpha particles would move through the gold with only minimal deflection.

CHALLENGE

4.1A: How can you tell what is inside?
Go to page 192.

CHALLENGE

4.1B: Rutherford model of the atom
Go to page 193.

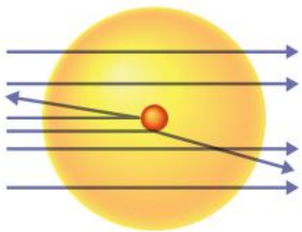


Figure 4 The gold foil experiment showed that some alpha particles were deflected.

Two aspects of the results surprised the scientists. The first evidence was that, while most of the alpha particles did pass straight through the gold foil, some alpha particles were deflected in different directions (Figure 4). Even more surprising was the second piece of evidence. A small number of the alpha particles bounced straight back in the direction that they had come from.

Rutherford concluded that, instead of being like a plum pudding, a gold atom must contain a lot of space, with a small positive charge in the centre that deflected the positive alpha particles. With his gold foil experiment, Rutherford had discovered a small, positively charged nucleus in the centre of the gold atoms.

Rutherford's model of the atom

Rutherford's model has been supported by further research on the structure of the atom. The current accepted model of an atom is as follows.

> The **nucleus** of an atom is made up of protons and neutrons.

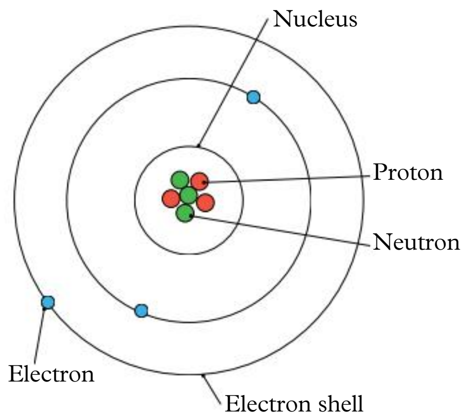


Figure 5 A two-dimensional model of an atom of the element lithium

> **Protons** carry a positive electric charge.
> **Neutrons** are neutral – they have mass but no electric charge.
> Electrons have a negative electric charge.
> The mass of the atom is almost entirely due to the mass of the protons and neutrons in the nucleus; electrons have very little mass in comparison.
> Electrons move around in the space outside the nucleus.

Huge parts of atoms are empty space. If you expanded one atom to the size of the Gabba AFL football oval, the nucleus of that atom would be no bigger than a pinhead.

An important thing to know is that, overall, an atom has no electrical charge. In other words, there is always the same number of positive protons as negative electrons in any atom.

electron
a negatively charged particle in the nucleus of an atom

Thomson plum pudding model
an early model of the atom in which the positively charged nucleus has negatively charged electrons scattered through it, like a plum pudding

nucleus
the centre of an atom, containing protons (positive charge) and neutrons (no charge)

proton
a positively charged subatomic particle in the nucleus of an atom

neutron
a neutral (no charge) subatomic particle in the nucleus of an atom

4.1 Check your learning

Comprehend

1 Use the evidence described to **explain** why Rutherford concluded that:
   a an atom contains a lot of space
   b there is a central area of positive charge.
2 **Describe** Thomson's plum pudding model of the atom.
3 **Describe** the most important new understanding of the structure of the atom that Rutherford inferred from his experiment with alpha particles.
4 **Name** and **describe** three types of particles we now know are inside an atom.

Apply

5 Working with a partner, **create** a three-dimensional model of an atom from modelling clay or other suitable materials. Make sure you label all parts correctly and state which model of the atom you are representing.

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

4.2 Atoms have mass

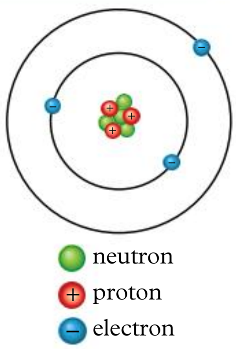
Key ideas

- The mass of an atom is made up of the protons and neutrons in the nucleus of the atom.
- Because atoms are so small, their mass is measured using a relative mass scale.
- Atoms are given their names according to the number of protons in their nucleus.

Learning intentions

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

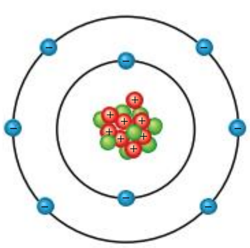
- describe how the elements are ordered on the periodic table
- explain the difference between atomic number and mass number.



Lithium

Number of protons = 3
Atomic number = 3
Number of neutrons = 4
Mass number = 7
Number of electrons = 3

Figure 1 A lithium atom, with mass number 7 and atomic number 3



Oxygen

Number of protons = 8
Atomic number = 8
Number of neutrons = 8
Mass number = 16
Number of electrons = 8

Figure 2 An oxygen atom, with mass number 16 and atomic number 8

Size is relative

A gold atom might seem heavy if you compare it to a helium atom. But if you compare it to an elephant, an atom is extremely small! To measure something by comparing it with something else is called relative measurement.

Relative scales are often helpful when objects or events are being compared. Relative scales are used when it is more important to know the differences between objects and events than the actual measurement (size, mass, time). The following conversation uses relative measurements.

> 'Mum, Chloe's been in the shower twice as long as I was.'
>
> 'I know, but you used three times as much shampoo.'

Being able to compare the masses of different atoms is important when investigating the behaviour of different atoms and elements. It is not so helpful to know the actual mass of atoms, partly because the mass is so small.

Mass number

On the relative atomic scale, the mass of a proton is given a value of 1. Neutrons have almost the same mass as protons, so they also have mass of 1 on this scale. Therefore, the mass of an atom (its mass number) can be worked out by counting how many protons and neutrons there are in the nucleus. Remember that electrons aren't included in the mass number, because they are so light in comparison to the particles in the nucleus.

For example, a helium atom that contains two protons and two neutrons has a relative mass of 4. A carbon atom that contains six protons and six neutrons has a relative mass of 12. The total number of protons and neutrons in an atom is also called the **mass number**.

Atoms are given different names according to the number of protons they have in the nucleus.

Because atoms are always neutral (no overall charge), the number of electrons in an atom is always the same as the number of protons (the atomic number). Figures 1 and 2 show examples of two common atoms.

Atomic number = number of protons

Protons determine names

There are many ways to group the different types of atoms. Because the mass of an atom is too small to be easily measured, and some atoms have similar properties, scientists use the number of protons to give an atom its name. An atom with 8 protons is always called oxygen, while an atom with 19 protons is always called potassium.

Representing atoms

When it is important to show the number of particles within each atom, the method of representation shown in Figure 3 can be used. The elements can be presented in a **periodic table** (Figure 4). In a periodic table, the elements are arranged according to the number of protons in their atoms. Hydrogen (1 proton) is given the atomic number of 1, followed by helium (2 protons), lithium (3 protons) and beryllium (4 protons). The vertical columns, called **groups**, consist of elements that behave in similar chemical ways. The horizontal rows are called **periods**.

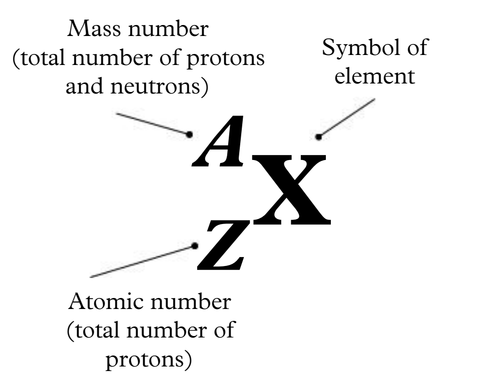


Figure 3 The conventional representation of an element

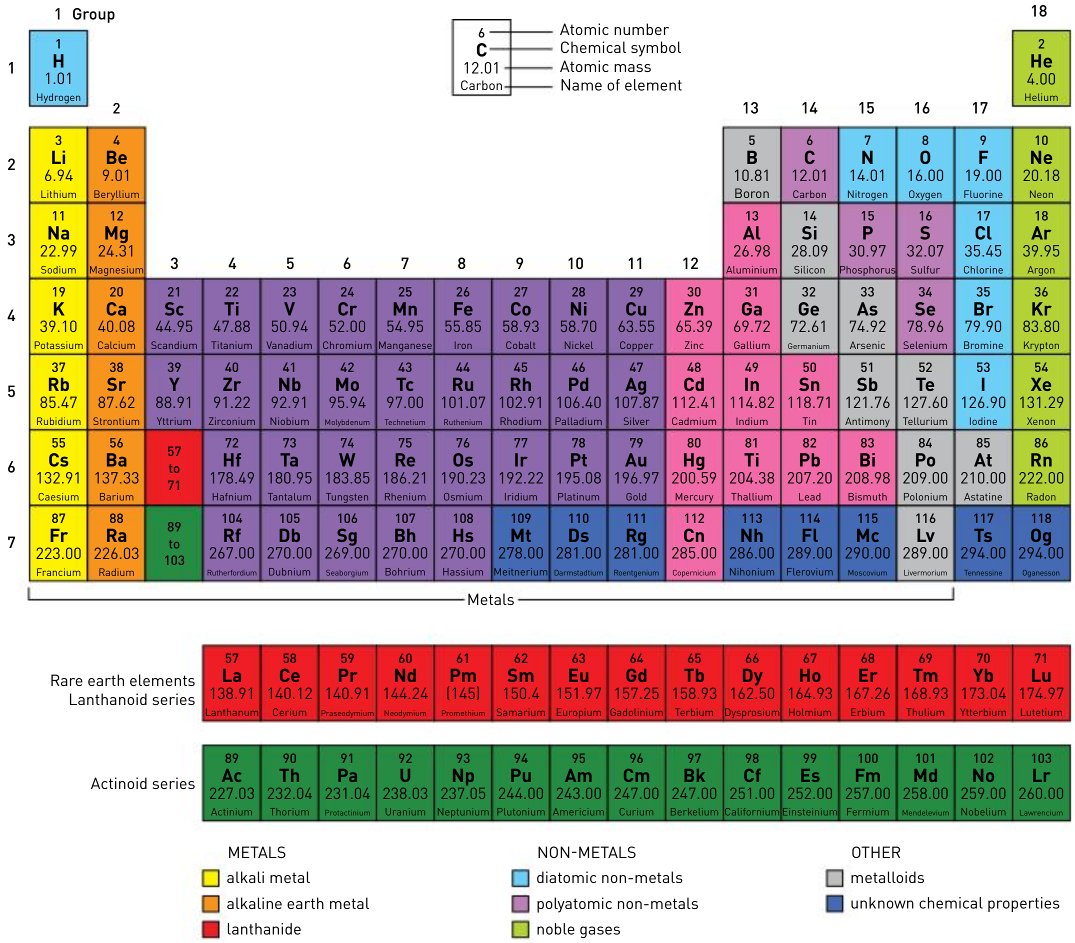


Figure 4 A periodic table of the elements

mass number
a number that represents the total number of protons and neutrons in the centre of an atom

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

group
a vertical list of elements in the periodic table that have characteristics in common

period
(in chemistry) a horizontal list of elements in the periodic table

4.2 Check your learning

Retrieve

1 **Identify** the subatomic particle that is not in the nucleus of the atom.

Comprehend

2 Table 1 shows the numbers of subatomic particles in a range of atoms.

a Complete the table.

Table 1 Atoms and subatomic particles

Atom name and symbol	Atomic number	Mass number	Number of protons	Number of neutrons	Number of electrons
Calcium (Ca)	20	40	20	20	20
Fluorine (F)	9	19	9		
Sodium (Na)	11		11	12	
Argon (Ar)		40	18		
Sulfur (S)			16	16	

b **Explain** how you were able to calculate the number of neutrons in the argon atom.

c **Explain** how you were able to work out the atomic number and the mass number of the sulfur atom.

3 Imagine that the elements do not have names and are identified only by their atomic numbers. **Describe** the possible complications this would cause.

Analyse

4 **Identify** the element that is located in period 3, group 15 of the periodic table.

5 The atomic number of a nitrogen atom is 7 and the mass number is 14. **Calculate** the number of electrons in this neutral atom.

6 **Identify** the atom that has twice as many protons as an oxygen atom.

Apply

7 **Investigate** what uranium-235 atoms are used for, and how many protons and neutrons are inside the nucleus of the atom.

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

4.3 Isotopes have more or less neutrons

Learning intentions

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

- define isotope and relative atomic mass
- compare the structure of isotopes of the same element
- explain how the relative mass of an element is calculated.

Key ideas

- An isotope is a different form of the same element with a different number of neutrons in the nucleus of the atom.
- The periodic table lists the relative atomic mass of an atom, which represents the average mass of all the isotopes of that atom.

Atomic mass and isotopes

The periodic table lists the atomic masses of the elements. These masses are not whole numbers and are not the same as the mass numbers of the atoms (although they are close). They are a more accurate way of comparing the masses of the atoms of different elements. But why are many of them not whole numbers? We certainly cannot have part of a proton or part of a neutron in an atom. Electrons do have some mass, but not enough to make much difference to the overall mass of the atom. So where do these atomic masses come from?

Generally, not all the atoms within an element have the same mass. This is because they are not identical. Why is this? What do they have in common and what is different?

All the atoms of an element have the same number of protons – their atomic number. The atomic number is used to identify the element. For example, all carbon atoms have six protons in their nucleus, so their atomic number is 6. In the periodic table of the elements (Figure 1), you can see that the elements are listed in order of their atomic number. However, although all the atoms of one particular element have the same number of protons, they may have different numbers of neutrons.

Isotopes

Neutrons help to make the nucleus more stable. For most elements, the number of neutrons in the atoms can vary. For example, most carbon atoms have six neutrons in their nucleus but some have seven or eight. The different forms of the atoms of an element that have different numbers of neutrons are called **isotopes**.

Remember, the number of protons in an element never changes. If there is a different number of protons, it is a different element.

isotope
an atom of a particular element that has more or fewer neutrons in its nucleus than another atom of the same element

21 Sc 44.95 Scandium	22 Ti 47.88 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.95 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.70 Nickel	29 Cu 63.55 Copper	30 Zn 65.39 Zinc
39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.94 Molybdenum	43 Tc (98) Technetium	44 Ru 101.07 Ruthenium	45 Rh 102.91 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.87 Silver	48 Cd 112.41 Cadmium
57 to 71	72 Hf 178.49 Hafnium	73 Ta 180.95 Tantalum	74 W 183.85 Tungsten	75 Re 186.21 Rhenium	76 Os 190.23 Osmium	77 Ir 192.22 Iridium	78 Pt 195.08 Platinum	79 Au 196.97 Gold	80 Hg 200.59 Mercury
89 to 103	104 Rf (205) Rutherfordium	105 Db 105 Dubnium	106 Sg (271) Seaborgium	107 Bh (272) Bohrium	108 Hs (277) Hassium	109 Mt (276) Meitnerium	110 Ds (281) Darmstadtium	111 Rg (280) Roentgenium	112 Cn (285) Copernicium

Figure 1 Some atomic numbers and atomic masses in the periodic table

CHALLENGE
4.3: Calculating relative atomic mass
Go to page **194**.

Carbon-12 is the most common form of carbon atom in the natural world. Of all the natural carbon on the Earth, only 1.1 per cent is carbon-13 atoms (6 protons and 7 neutrons), and an even smaller quantity is carbon-14 atoms (6 protons and 8 neutrons).

Like most elements, carbon has more than one naturally occurring isotope (Figure 2). In these cases, chemists use the average mass of the isotopes of the element for calculations. This average mass is termed the **relative atomic mass** of the element. For example, almost all carbon atoms exist as the carbon-12 isotope and only a very small proportion is present as the two heavier isotopes. Therefore, the relative atomic mass is only just above 12. The relative atomic masses of the elements are usually shown in the periodic table, correct to one or two decimal places. Be careful not to confuse atomic masses in the periodic table (which are decimals) with their atomic numbers (which are always integers).

relative atomic mass
the average mass of an element, including the mass and prevalence of its different isotopes

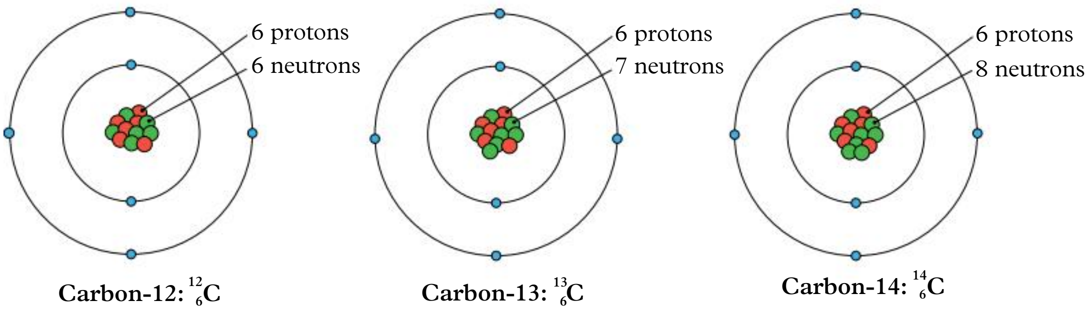


Figure 2 The three isotopes of carbon

Figure 3 Marie Curie was one of the first scientists to study isotopes, some of which are radioactive. Her notebook is still radioactive over 100 years later.

4.3 Check your learning

Retrieve

1 **Define** the term 'isotope'.

Comprehend

2 **Explain** the meaning of 'mass number' and how this name arose. Use an example to assist your explanation.

3 **Explain** why the atomic number of an element is always a whole number but the relative atomic mass of an element is often not a whole number.

Analyse

4 **Identify** which of the atoms below are isotopes of the same element. Also **identify** the name and symbol of the element.
Option 1: 5 protons, 5 neutrons
Option 2: 5 protons, 6 neutrons
Option 3: 6 protons, 6 neutrons

5 Use your knowledge of isotopes and a copy of the periodic table to complete Table 1.

Table 1 Isotope details

Isotope symbol	Isotope name	Atomic number of element	Number of protons	Number of neutrons	Number of electrons in uncharged atom
$^{238}_{92}U$					
	Oxygen-16				
			10	20	
				36	29
		30		34	

6 **Compare** the structure of two isotopes of the same element.

Apply

7 One atom has 5 protons and the other has 6 protons. Is this an example of a pair of isotopes? **Justify** your answer (by providing your reasons).

8 A student wrote that all the atoms of an element are identical. **Evaluate** whether this is correct (by defining the terms 'atom' and 'element', comparing the isotopes of carbon, and deciding whether the isotopes are identical).

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

4.4 Isotopes can release alpha, beta or gamma radiation

Learning intentions

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

- define radioactive decay, radionuclide, alpha radiation, beta radiation and gamma radiation
- describe the relationship between a half-life and the number of atoms of a substance.

Key ideas

- Some isotopes are unstable and may decay.
- Radioactive decay produces alpha, beta and/or gamma radiation.
- The half-life of an isotope is the time it takes for half the remaining unstable isotopes to decay.

radioactive decay
the conversion of a radioactive isotope into its stable form, releasing energy in the form of radiation

radionuclide
a radioactive isotope

alpha particle
a radioactive particle containing two protons and two neutrons; can be stopped by a piece of paper

beta particle
a radioactive particle (high-speed electron or positron) with little mass; can be stopped by aluminium or tin foil

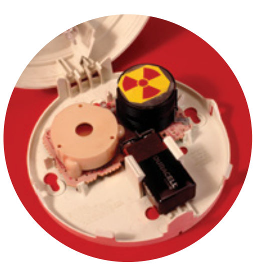


Figure 1 Smoke detectors contain a radioactive source, usually americium-241.

Isotopes and radioactive decay

In Topic 4.3, you learned about isotopes. Hydrogen, for instance, has three isotopes: hydrogen-1 $\left({}^{1}_{1}\text{H}\right)$, hydrogen-2 $\left({}^{2}_{1}\text{H}\right)$ and hydrogen-3 $\left({}^{3}_{1}\text{H}\right)$.

While the number of neutrons can vary, having too many or too few neutrons results in an unstable nucleus that decays radioactively. In the first 20 elements, stable nuclei have a similar number of neutrons and protons.

This process of decay causes the emission of radiation and is known as **radioactive decay**. Hydrogen-1 and hydrogen-2 are stable, but hydrogen-3 is unstable and breaks down. Therefore, hydrogen-3 is a radioactive isotope and is called a **radionuclide**. Radionuclides occur naturally but they can also be manufactured in a nuclear reactor. All radionuclides release radiation when they breakdown and form a more stable atom.

Types of nuclear radiation

Alpha (α), beta (β) and gamma (γ) radiation all originate from an unstable nucleus. An **alpha particle** is identical to a helium nucleus. It contains two protons and two neutrons. Americium-241, which is commonly used in smoke detectors, is an example of an alpha particle emitter. Its nucleus decays to neptunium-237, which is a more stable atom.

The decay of americium-241 to neptunium-237 can be shown in a nuclear equation:

$$^{241}_{95}\text{Am} \rightarrow {}^{237}_{93}\text{Np} + {}^{4}_{2}\alpha$$

In a nuclear equation, the mass numbers on each side of the arrow add to the same value. In this case, they both add to 241. This demonstrates that the total mass of the particles before and after the decay is the same.

Beta particles are produced when a neutron in the nucleus decays into a proton and an electron. The electron is the beta particle that leaves the atom. An example of beta decay is the decay of iodine-131 to xenon-131:

$$^{131}_{53}I \rightarrow {}^{131}_{54}Xe + \beta$$

The beta particle has very little mass, so the mass of the new nucleus formed is very similar to the original iodine-131 nucleus. As the beta particle is released, a neutron in effect becomes a proton, so the atomic number of the resulting nucleus increases by one.

Gamma rays are high-energy electromagnetic rays, similar to X-rays, which are emitted after alpha particle or beta particle emission when the nucleus is still excited.

An example is when cobalt-60 decays to form nickel-60:

$$^{60}_{27}\text{Co} \rightarrow {}^{60}_{28}\text{N} + \beta + \gamma$$

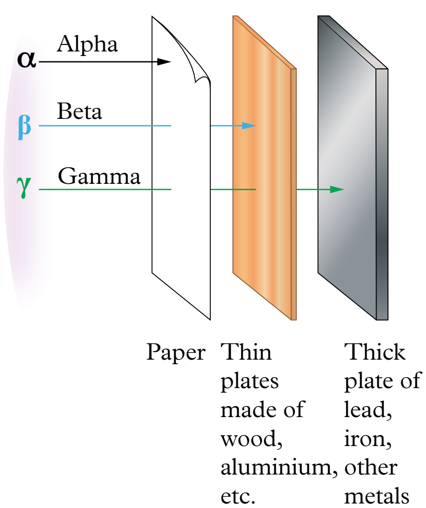


Figure 2 The relative penetrative power of alpha, beta and gamma radiation. Alpha particles are stopped by paper. Beta particles are stopped by aluminium foil. Gamma rays can only be stopped by lead.

CHALLENGE

4.4: Modelling radioactive decay
Go to page **195**.

Cobalt-60 is an artificially produced radioisotope that is used in medical radiotherapy, sterilisation of medical equipment and irradiation of food. Because gamma radiation is an electromagnetic wave (rather than particles, such as alpha and beta radiation), it is highly penetrating and can cause cell damage deep within the body if exposure levels are high.

Radioactive half-life

Radioactive decay is a random process, so we cannot predict which radioactive nuclei in a sample will decay. However, the rate of radioactive decay follows a pattern. As a radioactive sample decays, less and less of the original radioactive atoms are left and more of the alternative stable atoms are formed. This means the radioactivity level drops. The **half-life** of a radioactive material is the time taken for half the radioactive nuclei in a sample to decay into the stable atoms (see examples in Table 1).

This is also equivalent to the time taken for the radioactivity to drop to half of its original value.

When the radioactivity reaches one-half of its original level, one half-life has passed. When it reaches one-quarter of its original level, two half-lives have passed, and the pattern continues. A graph of radioactive decay against time gives a characteristic shape called an exponential decay curve (Figure 3). Worked example 4.4 shows how to calculate the half-life of a radioactive element.

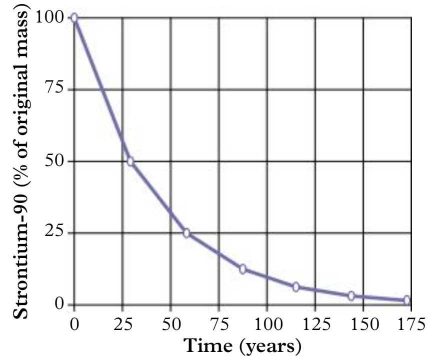


Figure 3 A radioactive decay curve for strontium-90, which has a half-life of 28.8 years

Table 1 Half-lives of important medical radionuclides

Radionuclide	Half-life
Bismuth-213	46 minutes
Technetium-99m	6 hours
Lutetium-177	6.7 days
Iodine-131	8 days
Chromium-51	28 days
Strontium-89	50 days

gamma rays
high-energy electromagnetic rays released as a part of radioactive decay; can be stopped by lead

half-life
the time it takes the radioactivity in a substance to decrease by half

Worked example 4.4: Calculating half-life

Strontium-90 is a radioactive element that has a half-life of 28.8 years. For 1000 g of strontium-90, calculate:

a the amount of strontium-90 left after 1 half-life

b the number of years it would take for the strontium-90 to decay to 125 g.

Solution

a After 1 half-life, half of the 1000 g would have decayed.

Remaining strontium-90 $= \frac{1}{2} \times 1000\,\text{g}$

$= 500\,\text{g}$

b To calculate the number of years it would take 1000 g to decay to 125 g, the number of half-lives needs to be determined.

Starting strontium-90 mass (0 years) = 1000 g

1 half-life (28.8 years) = 500 g

2 half-lives (57.6 years) = 250 g

3 half-lives (86.4 years) = 125 g

Therefore, the time for 1000 g of strontium-90 to decay to 125 g = 86.4 years.

4.4 Check your learning

Retrieve

1 **Define** each of the following terms.

a radioactive decay **b** radionuclide **c** half-life

Comprehend

2 **Represent** an isotope for each of the following in the form $^{A}_{Z}X$. You may need to use the periodic table to determine the atomic number of the elements.

a iodine-131 **b** cobalt-60

c technetium-99 **d** fluorine-18

3 A number of the elements have radioactive isotopes. In each case, it is the nucleus of the atom that is unstable. **Describe** how you could protect yourself from each of the following types of radiation.

a alpha **b** beta **c** gamma

Analyse

4 At 3:00 pm, 80 000 atoms of a radionuclide were sitting on the bench. At 3:10 pm, after 10 minutes of radioactive decay, there were only 5000 of the original atoms left. (The others had decayed into a more stable isotope.)

a **Calculate** the half-life.

b **Explain** the relationship between the half-life of the radionuclide and the number of atoms it has.

Apply

5 **Investigate** one radioactive isotope that is used in medicine. **State** the symbol for the isotope and its uses.

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

4.5 The half-life of isotopes can be used to tell the time

Learning intentions

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

- describe how the half-life of a radioisotope can be used to tell the time
- explain how carbon dating works.

Key ideas

- Background radiation exists all around us, from radioactive material and in the form of cosmic rays from the Sun and space.
- The rate at which a radioactive material decays can be used to determine how long the material has been outside a living organism.

Carbon dating

Whether a nucleus is stable depends on the number of neutrons and protons in the nucleus. There is no easy formula that can be used to predict the stability of individual atomic nuclei, but some nuclei, such as carbon-12 nuclei, with six protons and six neutrons, are very stable. However, carbon-14, with eight neutrons in its nucleus, is less stable and will decay over time, giving out radiation to form a different atom. It's very slightly radioactive, but safe.

Carbon-14 is being formed all the time as cosmic rays enter Earth's upper atmosphere. Plants absorb this carbon-14 when they photosynthesise and the carbon-14 then enters the food chain.

Therefore, all living organisms, including humans, contain a certain amount of radioactive carbon-14 while they're alive. However, when an organism dies and stops eating new carbon-14, the carbon-14 in its body begins to decrease at a reliable rate, with a half-life of 5730 years.

We can measure the amount of carbon-14 to determine the age of many old artefacts up to 50 000 years old, including cave paintings and ancient scrolls. This method is called **carbon dating**.

Carbon dating is the most common way of dating ancient artefacts, and plant and animal material. It was used to measure the age of the Shroud of Turin (Figure 1), a linen cloth believed by many to have been used to wrap the body of Jesus Christ after his crucifixion. Carbon dating indicated that the Shroud of Turin was not as old as claimed.

carbon dating
a method of estimating the age of organic material, by comparing the amount of carbon-14 in the material with the amount in the atmosphere, knowing the rate at which carbon-14 decays over time

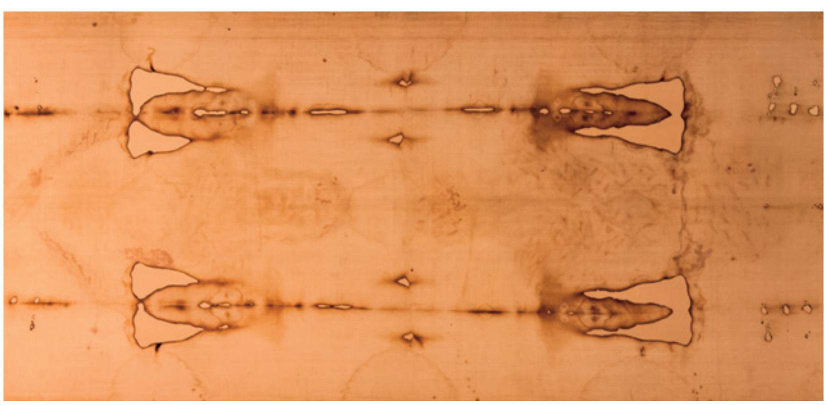


Figure 1 Carbon dating of the Shroud of Turin conducted in 1988 indicated that it was only 700–800 years old.

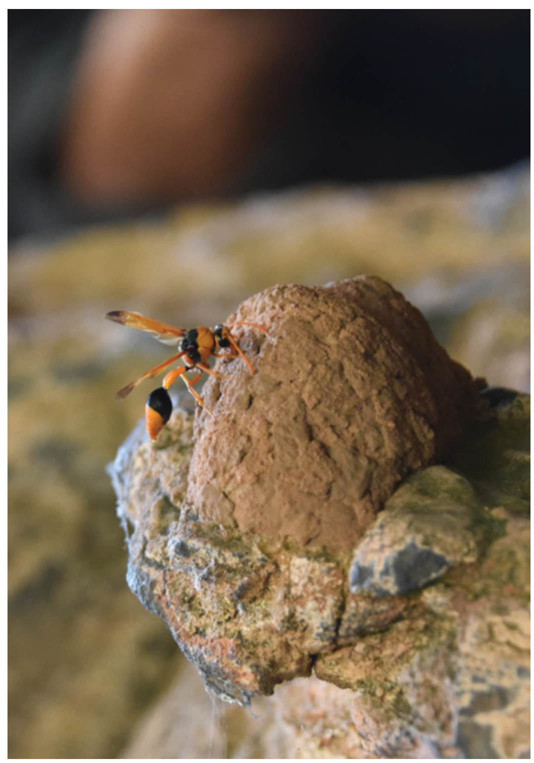


Figure 2 The amount of carbon-14 in a wasp nest can date rock paintings underneath.

Rock art is often difficult to date using carbon dating because the pigment does not usually contain carbon. The Australian Nuclear Science and Technology Organisation was able to solve this problem by dating a series of wasp nests built over the unique Gwion Gwion style art. With the permission of the traditional owners in the remote Kimberley, scientists were able to collect carbon formed in ancient bushfires from the fossilised wasp nests. The amount of carbon-14 remaining indicated that the paintings were at least 10–12 000 years old.

The decay of radioactive isotopes is often very slow. For example, 10 g of carbon-14 today would take 5730 years until half of it had decayed. The remaining 5 g would take another 5730 years to reduce to 2.5 g, and another 5730 to reduce to 1.25 g. Unless the amount of carbon is measured over an extremely long period, it might seem that no change is occurring.

Only sensitive equipment can detect the radiation being released during the decay process.

Some other radioactive atoms decay incredibly quickly. For example, half of a sample of the isotope lithium-8 decays in less than 1 second. Uranium-235 takes a very long time to decay: it would take 700 million years to reduce to half of the original amount.

In science, there are many situations where change takes place over a range of time scales. What makes radioactive decay special is that it is a random process. It is impossible to predict how long a particular atom will take to decay, giving out radiation as it does so. But with billions of atoms in any one sample, the overall rate of decay can be predicted. Think about a glass of water evaporating. It is impossible to predict when one particular water molecule will escape from the liquid, but overall it can be predicted how long the water will take to evaporate.

Figure 3 Carbon dating can be used to work out the age of an object.

4.5 Check your learning

Comprehend

1 **Explain** why carbon-12 atoms are more stable than carbon-14 atoms.

2 **Explain** why an isotope that decays very quickly would be considered more dangerous than an isotope that decays slowly.

3 **Describe** one way you might absorb new carbon-14 atoms into your body.

4 In 1988, carbon dating indicated that the Shroud of Turin was in fact created in the Middle Ages (between 1260 and 1390).

  a **Explain** how carbon dating is used to determine the age of an object.

  b **Explain** why this method dated the shroud to a range of years rather than a single year.

5 **Describe** how wasp nests can be used to date rock paintings.

Analyse

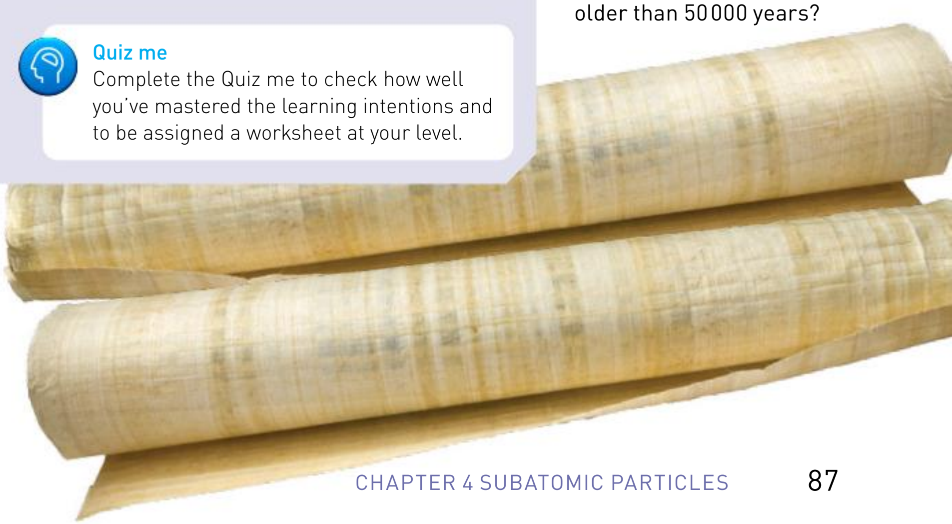
6 Carbon dating can be used to determine the age of objects less than 50 000 years old.

  a **Consider** why carbon dating cannot be used to determine the age of older objects (by calculating the number of half-lives that will have passed, and describing whether the remaining carbon-14 could be detected).

  b **Identify** another radioactive isotope with a longer half-life that could be used to date objects that are older than 50 000 years.

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

Figure 4 How can we determine the age of objects that might be older than 50 000 years?



//SCIENCE AS A HUMAN ENDEAVOUR//

4.6 Radiation is used in medicine

Learning intentions

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

- describe the effects of radiation on the human body
- provide examples of the use of radiation in medicine.

The radiation produced by isotopes can damage the cells in our body, or it can be used to identify and cure diseases. Nuclear medicine is a diagnostic imaging method often used in X-ray departments in hospitals and medical clinics.

Effects of radiation

The main reason that radiation can be harmful is that it can cause atoms in other substances to become ions. The emitted alpha and beta particles have enough mass and/or energy to remove electrons from the outside of atoms, which changes the properties of the atoms. This process also causes the release of reactive particles, called free radicals. If this occurs in our bodies, these free radicals can go on to damage other important molecules in the body. If DNA is damaged, this can have serious effects, because DNA is the molecule that contains instructions for other biochemical processes. It is also a molecule that can reproduce itself, so the effect of one damaged DNA molecule can be multiplied thousands or even millions of times as copies of the affected DNA are created. Many cancers linked to radiation start in this way.

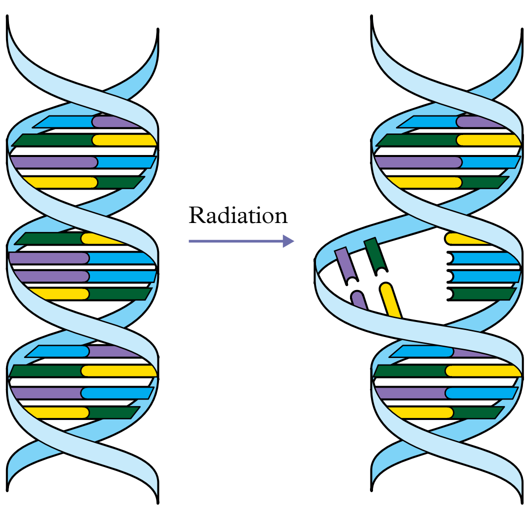


Figure 1 Radiation can damage the structure of DNA molecules.

Radiation and medicine

Despite the damage that can be caused by radiation, it has many uses in medicine. The most common medical application is the use of X-rays to identify damaged or broken bones. Less common is the injection of a radioactive isotope into a patient. The radiation accumulates at the site of a cancer or other damaged tissue, and is detected by special monitors.

Figure 2 X-rays use radiation to make images of the bones in the body.

Radiation therapy uses the ability of radioactive isotopes to kill off cancer cells. Cancer cells are normal cells that have had their DNA slightly changed. This change is not enough to kill the cancer cell. Instead, it allows the cancer cell to grow very quickly. Radiotherapy uses radioactive isotopes to cause more damage to the cancer cells. Most commonly, the radioactive particles released by the isotope are directed at the site of the cancer. Eventually, when the cancer cells are damaged enough, they die (a process called apoptosis).

Careers in radiation

A nuclear medicine technologist uses medical imaging to help radiologists diagnose illnesses. Before the first patient arrives, the technologist must measure the amount of radioactivity delivered to the department. The isotope, in liquid form, is drawn up into the required amounts and added to 'cold' kits so that the day's scans can be performed.

A cold kit is a vial containing a particular chemical agent that, once introduced into the human body, will travel to a particular organ. Each test uses a particular compound, which travels to a known organ of the body based on its chemical composition and the way it is introduced into the body.

Most people referred to nuclear medicine departments require bone scans.

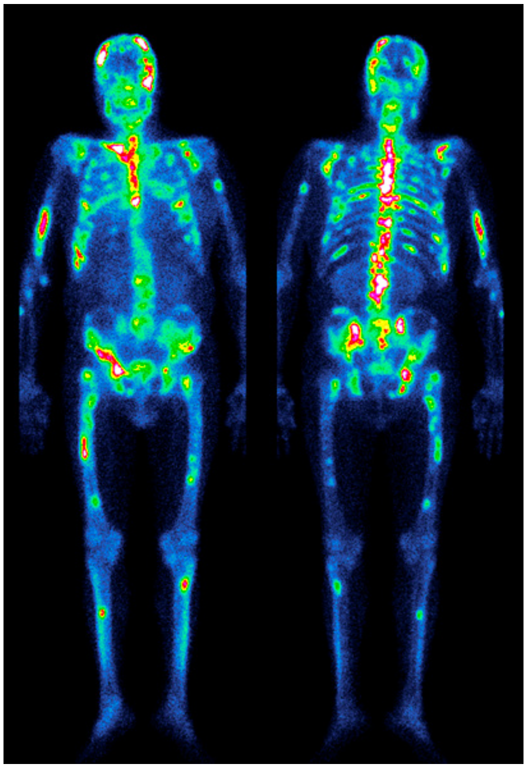


Figure 3 A technetium-99m bisphosphonate bone scan shows up abnormalities within bones.

These may be performed to diagnose cancer, investigate the extent of arthritis, screen for fractures that do not show on a plain X-ray, or look at infection of bone.

In other cases, the blood is of interest. The blood of a patient can be 'labelled' – mixed with a small amount of radionuclide. This is used to locate the site of an internal bleed. Once the bleed has been located, surgeons can operate knowing exactly where to begin finding the haemorrhaging vessel so that it may be sealed to prevent further blood loss.

The nuclear medicine technologist typically performs a number of these tests each day, looking at a variety of pathologies. Nuclear medicine technologists must be familiar with many organs in the body, in order to know whether the images obtained appear normal or abnormal. There is also the opportunity to learn about the various treatments for different conditions patients can have. Although a nuclear medicine technologist may learn to interpret images and determine what pathology a person has, they are are not qualified to make a formal diagnosis. They must present the images to the radiologist, who makes the diagnosis. Nuclear medicine technologists have a close working relationship with radiologists, surgeons and nurses.

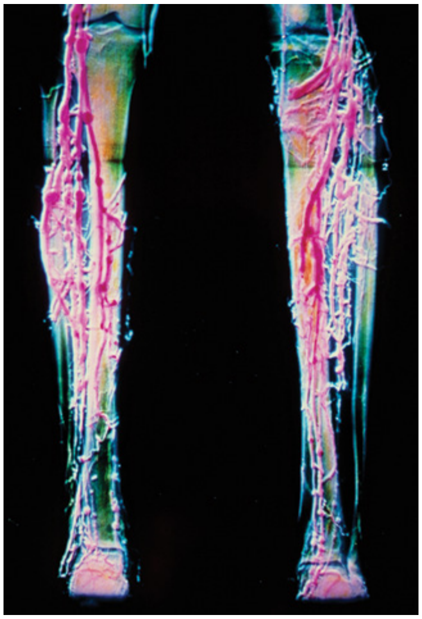


Figure 4 Radioactive dye injected into the blood shows blood flow in the blood vessels.

4.6 Test your skills and capabilities

Asking questions

In critical thinking, you are encouraged to ask many questions. However, it can sometimes be difficult to think of the right questions to ask. The best questions will have the following characteristics.

> Asking yourself specific questions is useful and can help identify assumptions that you or someone else may be making. For example: 'How do I know this?', 'What is the evidence that supports this?', 'Who wrote this?' and 'Why did they write this?'.

> Open questions are best when they are directed at someone else. An open question does not have a yes or no answer. Instead, it encourages the person to explain their response. For example: 'How do you feel about …?', 'Where do you think this idea came from?' and 'What makes you say that?'.

1 Write three questions that you could ask yourself or someone else about the radiation discussed in this chapter. They could be questions that identify any assumptions or biases that are held about radiation or cancer treatment.

2 Write three open questions that you could ask a nuclear medicine technologist about radiation or cancer treatment.

If you have access to a nuclear medicine technologist, ask them the questions you wrote in question 2. Alternatively, ask someone in your class to answer the questions you wrote in question 1. A good question will make them think critically before they provide an answer.

CHAPTER 4 REVIEW

SUBATOMIC PARTICLES

Retrieve

1 **Identify** the composition of the nucleus of an atom.
- A made of protons and neutrons
- B made of electrons and neutrons
- C made of protons and electrons
- D always negatively charged

2 Rows of the periodic table are called:
- A groups
- B periods
- C valences
- D electron configurations.

3 John Thomson suggested that an atom is like a plum pudding. **Recall** what the 'cake' and the 'fruit' represent.

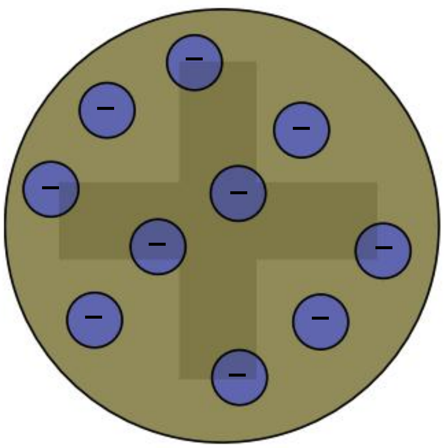


Figure 1 Thomson's plum pudding model

4 **Identify** the atomic numbers of the following elements using Figure 2.
- a mercury
- b tungsten
- c nickel
- d zirconium

21 Sc 44.95 Scandium	22 Ti 47.88 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.95 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.70 Nickel	29 Cu 63.55 Copper	30 Zn 65.39 Zinc
39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.94 Molybdenum	43 Tc (98) Technetium	44 Ru 101.07 Ruthenium	45 Rh 102.91 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.87 Silver	48 Cd 112.41 Cadmium
57 to 71	72 Hf 178.49 Hafnium	73 Ta 180.95 Tantalum	74 W 183.85 Tungsten	75 Re 186.21 Rhenium	76 Os 190.23 Osmium	77 Ir 192.22 Iridium	78 Pt 195.08 Platinum	79 Au 196.97 Gold	80 Hg 200.59 Mercury
89 to 103	104 Rf (205) Rutherfordium	105 Db 105 Dubnium	106 Sg (271) Seaborgium	107 Bh (272) Bohrium	108 Hs (277) Hassium	109 Mt (276) Meitnerium	110 Ds (281) Darmstadtium	111 Rg (280) Roentgenium	112 Cn (285) Copernicium

Figure 2 A section of the periodic table

5 **Identify** what each arrow represents in Figure 3.

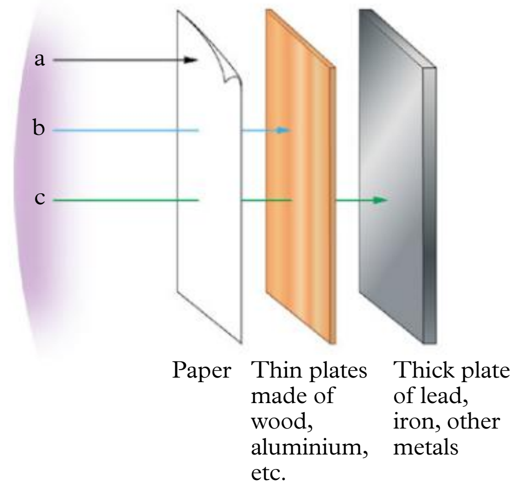


Figure 3 What does each arrow represent?

Comprehend

6 Complete the following sentence.
'When an atom is uncharged, the number of protons and the number of electrons present are _________.'

7 **Describe** where each of the following particles is found in an atom, and **identify** its charge as positive, negative or neutral.
- a proton
- b neutron
- c electron

8 **Explain** why the mass numbers of isotopes are whole numbers but the relative masses of most atoms are not whole numbers.

9 **Explain** how radiation can both cause cancer and be used to treat cancer.

10 **Describe** a beta particle. **Identify** its symbol, including the atomic and mass numbers in the correct positions.

11 **Explain** what is meant when a substance is described as radioactive.

12 **Explain** why molecules of water are impossible to see, even with a powerful microscope.

Analyse

13 Use the periodic table on page 81 to **identify** the correct statement about calcium.

- **A** It is in period 2.
- **B** It has an atomic number of 20 and a mass of 40.08.
- **C** Its electron configuration is 2,8,6,2.
- **D** It has six electrons.

14 Only 0.7 per cent of the uranium atoms in naturally occurring uranium exist as uranium-235. The other isotopes present are uranium-234 (0.01 per cent) and uranium-238 (99.3 per cent). **Identify** the symbols for the other two uranium isotopes.

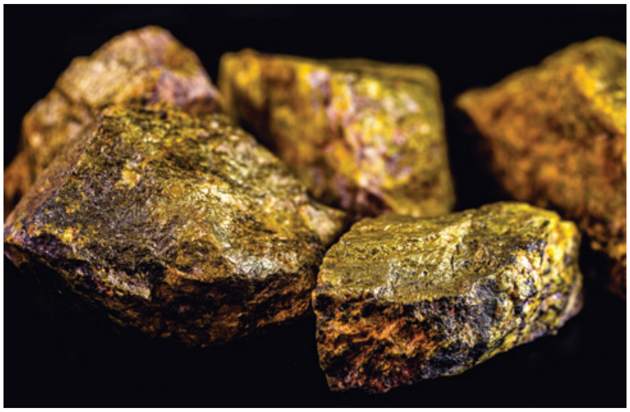


Figure 4 Uranium-238 has a relative atomic mass of 92.

15 **Compare** the different types of radiation (alpha, beta and gamma).

16 Titanium is element 22 in the periodic table. It has five naturally occurring isotopes. **Compare** (the similarities and differences between) the isotopes of titanium.

17 Tellurium is element number 52. It has a relative atomic mass of 127.6. The next element, iodine, has a relative atomic mass of 126.9.

- **a** **Identify** the symbols for the isotopes of tellurium-127 and iodine-127.
- **b** **Explain** why the atoms of these two elements can have the same mass number.

18 **Compare** Dalton's model of an atom to the model proposed by Rutherford.

19 If a radioactive substance decays from 400 counts per minute to 50 counts per minute in 9 hours, **calculate** its half-life.

20 $^{235}_{92}U$ is an isotope of uranium that is used in nuclear reactors. In an uncharged atom, **calculate** how many:

- **a** protons are present
- **b** neutrons are present
- **c** electrons are present.

Apply

21 Sketch a radioactive decay curve for a substance that starts with an activity of 1600 counts per minute and has a half-life of 2 hours.

22 Scientists have had to infer what the inside of an atom is like from indirect evidence, in the same way that astronomers have worked out the temperature and composition of stars. **Discuss** the advantages and disadvantages of using indirect evidence to develop theories in science.

Social and ethical thinking

23 Radiation can be used as a form of treatment to kill cancerous cells. However, this treatment can also damage cells in other parts of the body, causing side effects such as nausea, hair loss and fatigue. **Discuss** what is meant by the expression 'The end justifies the means'.

Critical and creative thinking

24 A primary school student who was learning about solids, liquids and gases was told by her teacher that everything around her is made of particles that she cannot see. Her response was that this is silly, because if you can't see it, it can't be there. **Develop** three critical thinking questions that the student may want to ask her teacher.

25 **Create** a poster that shows the different models of the atom, from the original theory that it was a solid particle, as proposed by English chemist John Dalton, to Rutherford's model. Use the internet to find images of the scientists involved and their models. Place copies of these onto your poster. **Investigate** the year in which each model was proposed and include a timeline.

26 Use your understanding of atoms and elements to **propose** reasons for the following.

- **a** Carbon dioxide is a heavier gas than oxygen.
- **b** Hydrogen and oxygen can be produced from water.
- **c** The relative atomic mass of argon (atomic number 18) is higher than the relative atomic mass of potassium (atomic number 19).
- **d** Beta particles can be stopped by a few millimetres of aluminium foil, but gamma rays will pass through aluminium foil.

Research

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

» Targeted alpha therapy

A cancer cell is a normal cell in the body that is growing in an uncontrolled way. This growth often means that cancer cells have different markers on their surface which makes them easier to identify. Targeted alpha therapy (TAT) uses special molecules that carry alpha radioactive particles to stick to the markers on a cancer cell.

- Describe how this form of therapy works.
- Describe the types of cancer that are treated by this method.
- Describe how widespread its use is.
- Identify the risks associated with this form of radiotherapy and how are they reduced.

» CERN

The European Organization for Nuclear Research (CERN) is based on the border of France and Switzerland. It has been responsible for developing scientists' understanding of atoms.

- Identify the countries that collaborate in this project.
- Describe the types of scientists who work at CERN.
- Describe the work that is occurring at CERN.
- Describe the Large Hadron Collider.

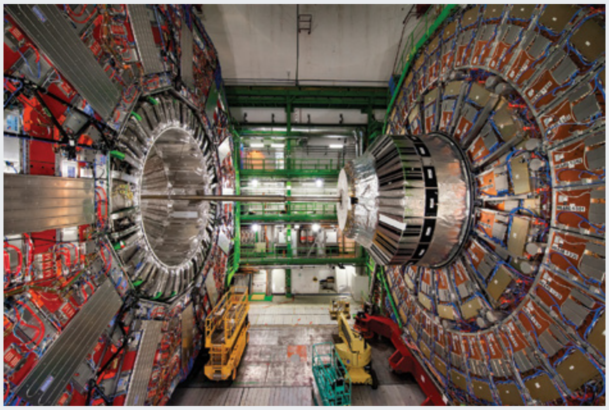


Figure 5 Part of the Large Hadron Collider

» Earliest evidence of First Nations peoples of Australia

In 2012 and 2015, the Mirarr Traditional Owners gave permission for scientists to excavate the Madjedbebe rock shelter near Kakadu. Carbon dating and optically stimulated luminescence (OSL) were used to date artefacts found at the site and, so also, the age that First Nations peoples were present in Australia.

- Explain why the permission of the Traditional Owners was needed before any testing could occur.
- Identify the artefacts that were found at the site.
- Describe how the age of the samples was determined.
- Identify the age of the samples.
- Describe the significance of this date to the theory that First Nations peoples arrived in Australia 40 000 years ago.

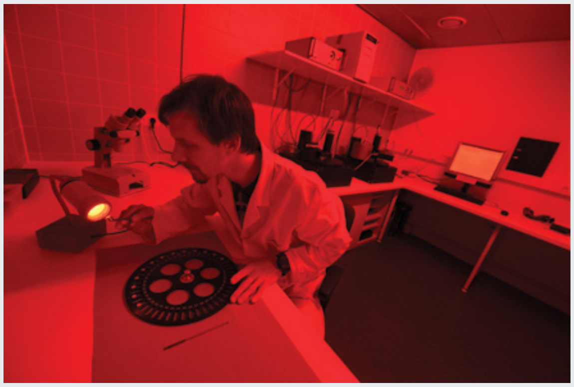


Figure 6 OSL dating determines when minerals were last exposed to sunlight.

Chapter checklist

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

	I can do this.	I cannot do this yet.
• Define atomic theory, electron, Thomson plum pudding model, nucleus, proton and neutron. • Describe the Rutherford model of an atom.	☐	☐ Go back to Topic 4.1 'Atoms are made up of subatomic particles'. Page 78
• Describe how the elements are ordered on the periodic table. • Explain the difference between atomic number and mass number.	☐	☐ Go back to Topic 4.2 'Atoms have mass'. Page 80
• Define isotope and relative atomic mass. • Compare the structure of isotopes of the same element. • Explain how the relative mass of an element is calculated.	☐	☐ Go back to Topic 4.3 'Isotopes have more or less neutrons'. Page 82
• Define radioactive decay, radionuclide, alpha radiation, beta radiation and gamma radiation. • Describe the relationship between a half-life and the number of atoms of a substance.	☐	☐ Go back to Topic 4.4 'Isotopes can release alpha, beta or gamma radiation'. Page 84
• Describe how the half-life of a radioisotope can be used to tell the time. • Explain how carbon dating works.	☐	☐ Go back to Topic 4.5 'The half-life of isotopes can be used to tell the time'. Page 86
• Describe the effects of radiation on the human body. • Provide examples of the use of radiation in medicine.	☐	☐ Go back to Topic 4.6 'Science as a human endeavour: Radiation is used in medicine'. Page 88

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Play a Quizlet game to test your knowledge.

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

CHAPTER

5

CHEMICAL REACTIONS

5.1 Mass is conserved in a chemical reaction

> Identify the reactants and products in a chemical reaction.

> Explain and apply the law of conservation of mass.

5.2 Balanced chemical equations show the rearrangement of atoms

> Desribe a chemical reaction.

> Write, balance and assign states to chemical reactions.

5.3 Chemical reactions are used to purify elements from ore

> Describe processes used to concentrate minerals and isolate metals.

> Use the reactivity series of metals to explain phenomena.

5.4 Science as a human endeavour: Green chemistry reduces the impact of chemicals on the environment

> Describe some green chemistry measures.

> Analyse and evaluate safety data.

What if?

Chemical reactions

What you need:

Vinegar, sodium bicarbonate, test tube, permanent marker

What to do:

1 Add a small amount of sodium bicarbonate to a test tube.

2 Pour a small amount of vinegar into the test tube.

3 Use the permanent marker to place a line at the height that the carbon dioxide gas bubbles reach.

What if?

» What if more vinegar was added?

» What if more sodium bicarbonate is added?

» What if the vinegar was heated?

5.1 Mass is conserved in a chemical reaction

Learning intentions

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

- identify the reactants and products in a chemical reaction
- explain and apply the law of conservation of mass.

Key ideas

- In chemical reactions, the starting chemical reactants are on the left-hand side of the arrow.
- In chemical reactions, the final chemical products are on the right-hand side of the arrow.
- The law of conservation of mass states that the total mass of the reactants is equal to the total mass of the products.

Representing chemicals

When examining chemical reactions, we can represent the substances in different ways. The substances that are present at the start of a chemical reaction are called the **reactants**. The substances formed by the chemical reaction are called the **products**. We can write this using a simple word equation. Consider the reaction between the acid in vinegar and sodium bicarbonate. This reaction produces water, carbon dioxide gas and a substance called sodium acetate, and it can be represented as:

acetic acid (in vinegar) + sodium bicarbonate → sodium acetate + carbon dioxide + water

The acetic acid and sodium bicarbonate are the starting chemicals (reactants) for this reaction. The products are the chemicals formed by the reaction. In this reaction they are sodium acetate, carbon dioxide and water.

The law of conservation of mass

Sometimes a reaction only has one reactant. For example, when mercury oxide is heated (one reactant) it can produce two products, mercury metal and oxygen gas.

Like all gases, oxygen has a mass. This means it can be weighed in grams on Earth. In an open system, the oxygen gas could escape. This means the reactant (mercury oxide) would weigh more before it was heated, than the weight of the mercury after heating because the oxygen would have escaped. This is different to a closed system, where the oxygen was not allowed to escape. In a closed system, the reactant (mercury oxide) would weigh the same as the products (mercury metal and oxygen gas). This is an important observation. It shows that the total mass of the chemicals is not changed in a chemical reaction.

When a chemical reaction takes place, the chemicals interact, causing the atoms to break apart from one another before forming into new arrangements. However, no atoms are produced in the process and no atoms are destroyed (Figure 1). This is one of the most important laws in science.

reactant
a substance used at the beginning of a chemical reaction; written on the left side of a chemical equation

product
a substance obtained at the end of a chemical reaction; written on the right side of a chemical equation

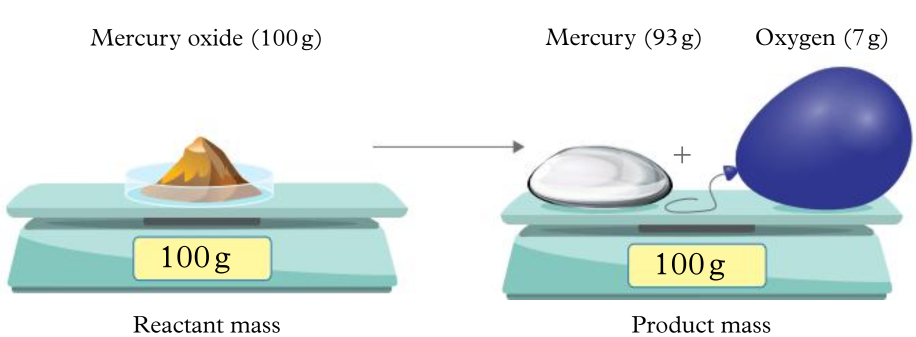


Figure 1 When mercury oxide (HgO) is heated, its atoms rearrange to form mercury liquid (Hg) and oxygen gas (O_2). The overall mass of reactants and products is the same – no atoms are destroyed, and no new atoms are created.

EXPERIMENT

5.1: Comparing mass before and after a chemical reaction
Go to page **196**.

Example of a chemical reaction

Methane gas (CH_4) is the main gas present in natural gas, which is used in the home for cooking and heating. When it burns, it combines with oxygen (O_2) in the air to form carbon dioxide (CO_2) and water (H_2O).

Figure 2 shows what happens to the atoms during this reaction. Different atoms are represented by different colours. Table 1 shows the different representations of the reactants and products.

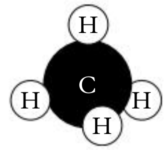
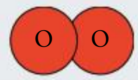
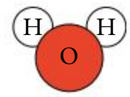
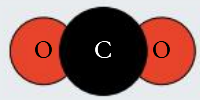
1 Count the number of each type of atom in the reactants (left-hand side of the arrow) and count the number of each type of atom in the products (right-hand side of the arrow). What do you notice?

2 Describe what has happened to the hydrogen atoms during the chemical reaction.

3 Describe what has happened to the oxygen atoms. Make sure you use the correct names of the chemicals in your description.

4 Write the chemical reaction as a word equation where the reactants are on the left-hand side and the products are on the right-hand side (Figure 2).

Table 1 Representations of four chemicals

Chemical name	Formula/symbol	Diagram
Methane	CH_4	
Oxygen	O_2	
Water	H_2O	
Carbon dioxide	CO_2	

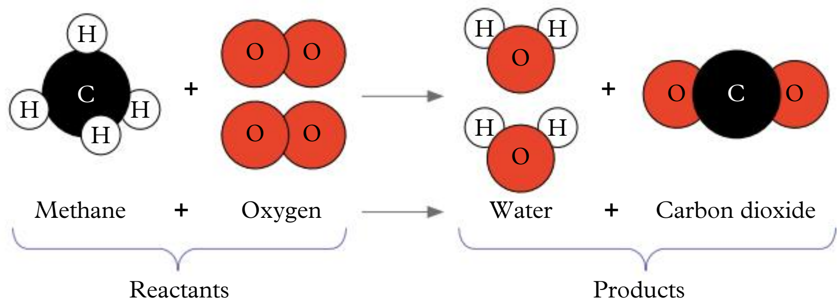


Figure 2 Atoms are rearranged during a chemical reaction.

5.1 Check your learning

Retrieve

1 **Define** the term 'mass'.

Comprehend

2 If no mass is lost or gained in a chemical reaction, **explain** what this tells you about the individual atoms involved in the reaction.

3 **Explain** why the products have properties very different from those of the reactants, even though the total mass remains the same.

4 **Represent** the following reaction as a word equation (by identifying the reactants and products):
Magnesium ribbon was burnt in the presence of oxygen to produce magnesium oxide.

Analyse

5 Use Table 1 to **identify**:
- a an element composed of molecules
- b a compound composed of molecules.

6 Early alchemists repeatedly tried to turn lead into gold. **Infer**, using the law of conservation of mass, why this would be impossible.

Apply

7 **Evaluate** each of the following equations to **determine** if they obey the law of conservation of mass (by comparing the number and types of atoms in the reactants to the number and type of atoms in the products and deciding if the atoms are conserved).
- a $C + O_2 \rightarrow CO_2$
- b $H_2 + O_2 \rightarrow H_2O$

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

5.2 Balanced chemical equations show the rearrangement of atoms

Learning intentions

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

- desribe a chemical reaction
- write, balance and assign states to chemical reactions.

Key ideas

- Chemical reactions can be described through observations, word equations or symbols.
- The law of conservation of mass is used to write a balanced chemical equation.
- A balanced chemical equation has equal numbers of each type of atom on both sides of the equation.

Describing chemical reactions

Perhaps you have seen sodium metal reacting with water at school or on the internet (Figure 1). This is a chemical reaction between the sodium metal and the water.

There are different ways to describe this reaction.

> *Describing observed changes:* The sodium metal dissolves in the water; heat is produced; fizzing is caused by the production of hydrogen gas. If there is enough heat, the hydrogen gas catches fire above the sodium metal.

> *Using a word equation:* The reactants are sodium and water and they interact to form the products, which are sodium hydroxide and hydrogen gas. A word equation summarises the changes:

sodium + water → sodium hydroxide + hydrogen

> *Using a chemical equation:* This includes the formulas of all the substances involved and the ratio in which they react:

$$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$$

Each representation tells us something different about the changes occurring in the chemical reaction.

Table 1 States and their symbols

State	Symbol
Gas	(g)
Liquid	(l)
Solid	(s)
Aqueous (dissolved in water)	(aq)

Figure 1 Sodium metal reacts violently with water, undergoing a chemical change.

Figure 2 The reaction of hydrogen with oxygen caused the *Hindenburg* explosion.

Reacting hydrogen and oxygen

When hydrogen gas burns in oxygen, large amounts of heat energy are produced. If this reaction happens in uncontrolled conditions, it is very dangerous (Figure 2). However, when used safely in a carefully controlled way, hydrogen can be an excellent renewable fuel that doesn't emit carbon dioxide. Car manufacturers are already developing hydrogen-fuelled cars. An advantage of using hydrogen as a fuel is that the only substance emitted in the exhaust is water vapour – there are no carbon dioxide emissions. Also, unlike fully electric cars, hydrogen cars do not need enormous, heavy batteries.

When hydrogen combusts with oxygen in the air, the oxygen atoms and hydrogen atoms split up from one another and join together to form water (H_2O). The atoms have not been created or destroyed. You can show what is happening by using a diagram or a chemical equation.

Balancing chemical equations requires a systematic approach where each atom is counted on both sides of the equation. Changing the number of one group of molecules (by changing the larger coefficients and not the subscripts) may affect a number of other atoms. It is important to continue to check and change the coefficients until all atoms are conserved. Worked example 5.2 illustrates how to write balanced chemical equations.

CHALLENGE
5.2: Modelling chemical equations
Go to page 198.

Worked example 5.2: Balancing equations

Write the chemical equation for the reaction below:

Hydrogen combines with oxygen to produce water.

Solution

The equation can be written by using the following steps.

1 Write out the word equation for the reaction.

hydrogen + oxygen → water

2 Write a simplified chemical equation using the formulas of each molecule involved. Identify the number of atoms in each molecule. For example, water is H_2O (two hydrogen atoms with a single oxygen atom) and hydrogen and oxygen exist as pairs of atoms. This is represented as subscripts (small numbers at the lower half of the symbol).

$H_2 + O_2 \rightarrow H_2O$

3 Work out the numbers of each type of atom in the reactants (left-hand side) and in the products (right-hand side), as shown in Table 2.

Table 2 Number of each type of atom in the reactants and products

	Reactants		→	Products	
Type of atom:	H	O	→	H	O
Number of atoms:	2	2		2	1

4 Compare the number of each type of atom in the reactants with the number in the product. In this case, there are four atoms in the reactants and three atoms in the products. This doesn't fit the law of conservation of mass. We can't have 'lost' an oxygen atom. We cannot change the subscripts (from H_2O to H_2O_2) because this would change water into hydrogen peroxide. Instead, we need to add a whole water molecule by including numbers (called coefficients) before the formula of the substances. This balances the number of oxygen atoms, but also doubles the number of hydrogen atoms (Table 3).

Table 3 The number of oxygen atoms is balanced

	Reactants		→	Products	
Type of atom:	H	O	→	H	O
Number of atoms:	2	2		4	2

$H_2 + O_2 \rightarrow 2H_2O$

The unbalanced hydrogen atoms can be balanced by doubling the number of hydrogen molecules (Table 4).

Table 4 Check the equation is balanced

	Reactants		→	Products	
Type of atom:	H	O	→	H	O
Number of atoms:	4	2		4	2

$2H_2 + O_2 \rightarrow 2H_2O$

This allows the number of reactant atoms to equal the number in the product – the equation is said to be balanced.

5 Add the state (solid, liquid or gas) of each molecule (Table 1).

$2H_2 (g) + O_2 (g) \rightarrow 2H_2O (l)$

5.2 Check your learning

Retrieve

1 **Recall** what the '(s)', '(l)', '(g)' and '(aq)' symbols represent in the chemical equation for the reaction of sodium metal with water.

Comprehend

2 **Explain** why chemical equations that are not 'balanced' are always incorrect.

Analyse

3 Balance the following equations by adding numbers as required:

a __Na + __H_2O → __NaOH + __H_2

b __H_2 + __O_2 → __H_2O

c __CH_4 + O_2 → __CO_2 + __H_2O

d __Mg + __HCl → __H_2 + __ $MgCl_2$

Apply

4 **Identify** which representation of a chemical reaction tells us most about the chemicals. **Justify** your answer.

5 Imagine one of your classmates missed this class and asked for your help to understand how to balance chemical equations. Consider how you would explain it to them. **Create** a set of instructions using the medium you think would be most useful (e.g. a written list, an illustrated poster, a presentation).

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

5.3 Chemical reactions are used to purify elements from ore

Learning intentions

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

- describe processes used to concentrate minerals and isolate metals
- use the reactivity series of metals to explain phenomena.

Key ideas

- Most elements are found as ore.
- The reactivity of an element determines how easy it is to extract.
- Extracting metals requires the concentration of the mineral and isolation of the metal.

Elements we need

We use a wide range of different elements and compounds in our everyday lives. The mobile phones, computers and cars we use rely on silicon, copper, gold, lithium and many other elements. Australia is one of the leading producers of bauxite (aluminium ore) and rutile (titanium dioxide), the second-largest producer of lithium, and the third-largest producer of iron ore and zinc.

Elements are rarely found in their natural state because of their ability to react with other elements around them. This means most chemicals that are found in the world around us are compounds. A naturally occuring element or compound is known as a **mineral**. Most rocks contain a mixture of minerals. A rock that contains a high percentage of one type of mineral is called an **ore**.

mineral
a naturally occuring element or compound

ore
a rock that contains a high percentage of one type of mineral

It is not easy or cheap to extract the element or mineral from the ore. If the amount of an element in the ore is high enough, then the cost of extracting the mineral and eventually the element will be worth the time and expense. Consider a chocolate chip muffin. If you want just the chocolate chip 'element' in the muffin, you will need to break away the muffin crumbs from the chocolate chips so that you can collect them. It takes time and effort to do this. If the number of chocolate chips per muffin is small, you might not think it worth the effort to extract them. You are more likely to look for a muffin that has a lot of chocolate chips present.

Reactive metals

Many of the minerals that we need to make modern products such as electronics are metals. Some metals are more reactive than others. This means that they are able to chemically react to produce a compound. When the reactivity of metals is arranged in order of most reactive to least reactive, it produces a reactivity series (Figure 1).

This reactivity series of metals is important when extracting a metal from its ore or mineral. A metal that is very reactive is more likely to bond with another atom in a chemical reaction. Metals found at the top of the table (potassium and sodium) are so reactive that they are never found in nature in their natural state. The less-reactive metals at the bottom of the table (gold and platinum) are more likely to be found as natural elements.

Metals	Reactivity
Potassium	Reacts with water
Sodium	Reacts with water
Lithium	Reacts with water
Barium	Reacts with water
Strontium	Reacts with water
Calcium	Reacts with water
Magnesium	Reacts with acids
Aluminium	Reacts with acids
Manganese	Reacts with acids
Zinc	Reacts with acids
Chromium	Reacts with acids
Iron	Reacts with acids
Cadmium	Reacts with acids
Cobalt	Reacts with acids
Nickel	Reacts with acids
Tin	Reacts with acids
Lead	Reacts with acids
Hydrogen	Included for comparison
Antimony	Highly unreactive
Bismuth	Highly unreactive
Copper	Highly unreactive
Mercury	Highly unreactive
Silver	Highly unreactive
Gold	Highly unreactive
Platinum	Highly unreactive

Figure 1 The reactivity series of metals

The types of minerals formed by reactive metals can be broken into three categories: carbonates (XCO_4), oxides (XO) and sulphates (XSO_4). Oxide minerals such as hematite (iron oxide), chromite (chromium oxide), manganite (manganese oxide) and rutile (titanium oxide) are usually found grouped together (Figures 2–4). Knowing the type of mineral can help determine the best extraction method for the metal.

Figure 2 Hematite is the oxide form of iron. Iron is used in the construction industry.

Figure 3 Chromite is an oxide form of chromium metal that is used as an industrial catalyst or pigment.

Figure 4 Manetite and rutile contain manganese and titanium.

Concentration of the mineral in the ore

Once the ore rocks have been extracted from the Earth's surface, the unwanted minerals need to be removed. There are several ways the important mineral can be concentrated.

Gravity separation

Some minerals are more dense than others. This difference in density can be used to separate the different metals containing minerals. Figure 5 shows the less dense materials being washed away, leaving the more dense material behind.

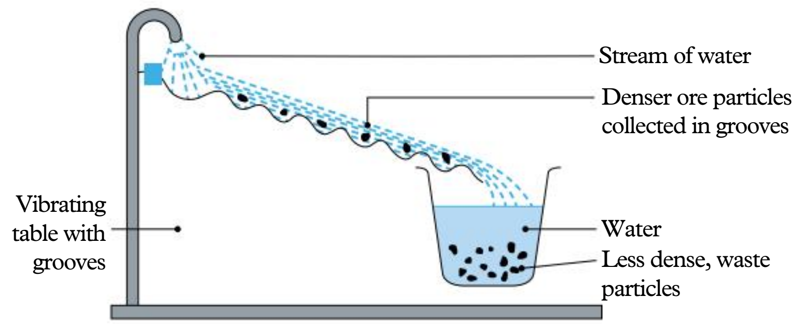


Figure 5 Gravity separation relies on heavy materials being left behind while the less dense materials are washed away.

Froth flotation

The crushed ore is added to water with a frother (similar to a detergent). When air is blown through the water, the important mineral (usually a sulfide or carbonate) will bubble to the surface with the froth (Figure 6).

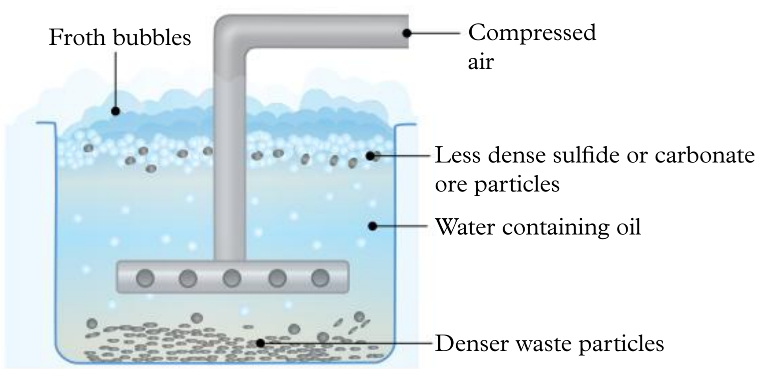


Figure 6 Less dense ore particles float to the surface.

Magnetic separation

If the crushed ore has magnetic properties, it is passed over conveyer belts with magnetic rollers (Figure 7). The rollers attract magnetic metal and allows it to be separated from unwanted minerals.

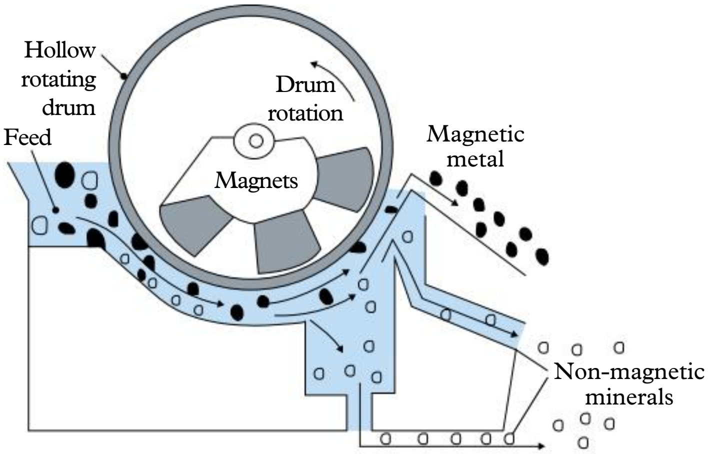


Figure 7 Magnets can be used to separate ore containing magnetic metals.

Leaching

Some ores of gold, silver and aluminium are heaped into a large pile and treated with a leaching solution such as sulfuric acid that dissolves the important mineral (Figure 8). The sulfuric acid containing the metal mineral (called a pregnant solution) is removed from the base of the heap. The metal ore is then isolated from the solution.

Isolation of metal from the ore

Just as there are different types of metal minerals (oxides, sulfides and carbonates), there are different chemical reactions that can be used to separate the metal elements from their compound. Which reaction is used is dependent on the reactivity of the metal. If the metal is more reactive (at the top of the reactivity series) then it will be more easily separated than a less reactive metal. The isolation processes are summarised in Figure 9.

Roasting

This process involves the heating of the metal ore, such as metal sulfide (MS) in the presence of oxygen (O_2). Because the oxygen is more reactive than sulfide, the metal will change from a metal sulfide to a metal oxide (MO), producing sulfur dioxide (SO_2) as well. The metal oxide can then undergo reduction.

$$2MS + 3O_2 \rightarrow 2MO + 2SO_2$$

Smelting

Smelting can be used to extract the metal from metal carbonates (MCO_3). It occurs when the ore is heated with carbon (C) in a limited air supply. It will produce a metal oxide (MO) and carbon dioxide (CO_2).

$$MCO_3 \rightarrow MO + CO_2$$

It can be more difficult to remove the last oxygen from some metal oxides. This is usually done through a reduction process.

Reduction

Reduction involves the removal of the oxygen from the metal oxide. If a metal is not very reactive, then the oxygen atom will be displaced to a more reactive metal. For example, copper is less reactive than aluminium. This means when the copper oxide is heated to a high temperature in the presence of aluminium, the oxygen will be displaced from the copper to the aluminium. Other metal oxides such as hematite can be purified using heat and carbon.

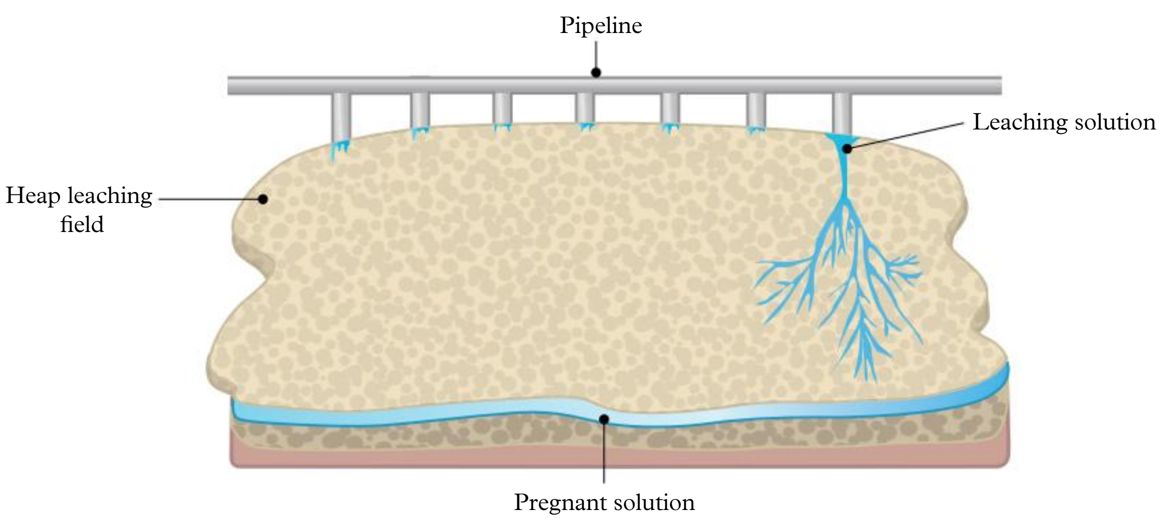


Figure 8 The metal mineral can be leached from the crushed ore using a leaching solution.

CHALLENGE
5.3A: Froth flotation
Go to page **199**.

EXPERIMENT
5.3B: Electrolysis of copper sulfate
Go to page **200**.

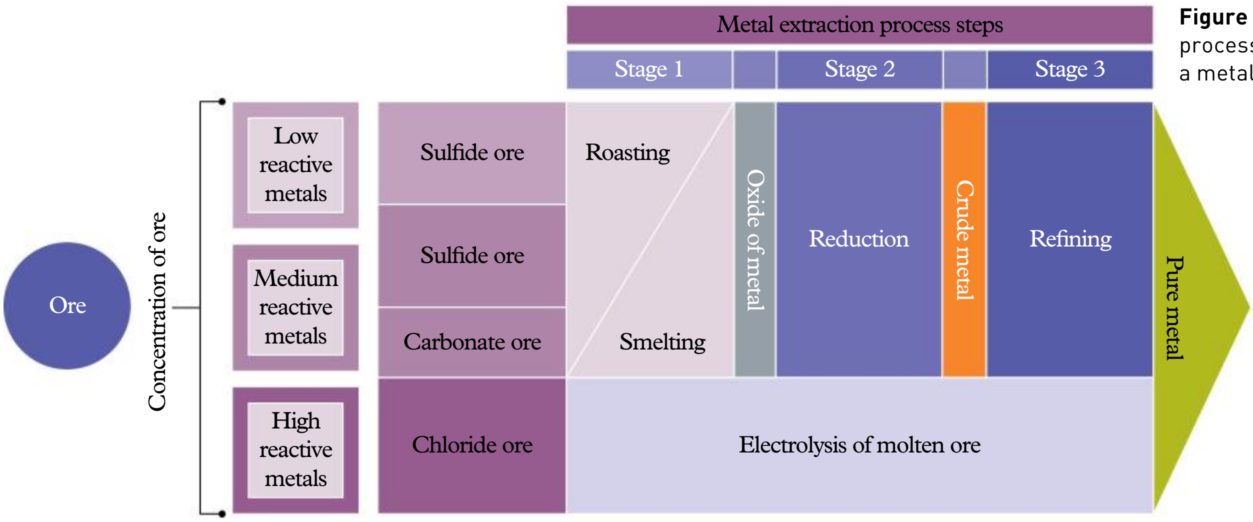


Figure 9 The different processes used to isolate a metal from its ore

When the metal oxide is combined with carbon at a high temperature, the oxygen binds with the carbon to form carbon dioxide.

$$2MO + C \rightarrow 2M + CO_2$$

Carbon cannot be used to remove the oxygen from the aluminium in bauxite, because the aluminium is more reactive than carbon. This means another method needs to be used.

Electrolysis

If a metal is highly reactive, like aluminium or lithium, it can be difficult to remove the metal oxide. This is because the metal is strongly attracted to the oxygen. When this occurs, extra energy is needed to remove the oxygen. Because the energy used is electricity, the process is called electrolysis (Figure 10).

The metal oxide is heated to a very high temperature (>1000°C) so that the different charged atoms are separated in a liquid form. To prevent them rejoining, the electrical current forces them apart, the positive atoms react at the negative electrode (cathode) and the negative atoms react at the positive electrode (anode).

Electrolysis can also be used to purify a metal by removing the impurities.

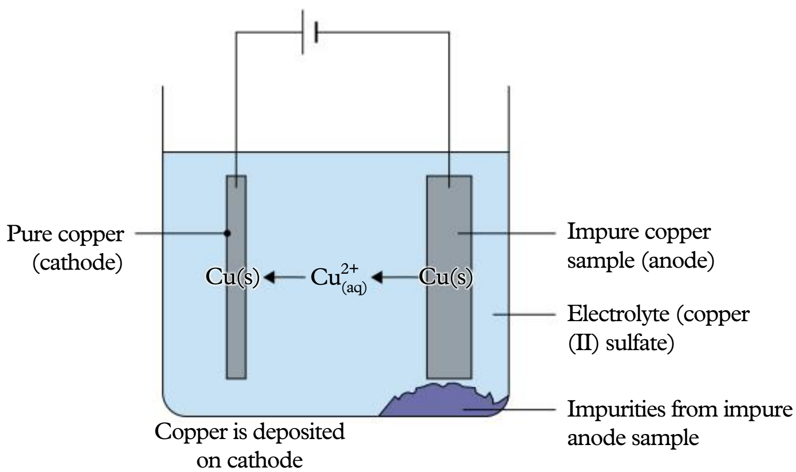


Figure 10 Electrolysis can be used to separate a metal from a mineral or to remove impurities.

5.3 Check your learning

Retrieve

1 **Define** the term 'ore'.

2 **Recall** the information contained in the reactivity series of metals.

3 **Identify** the elements that are found in the following ores.

   a hematite

   b rutile

Comprehend

4 **Describe** the processes that could be used to concentrate and isolate copper from malachite (a copper carbonate).

Apply

5 **Identify** which of gold or strontium are more likely to be found in their natural state in the environment. **Justify** your decision using the reactivity series of metals.

6 When left in the air too long, silver can tarnish (form a silver oxide). This can be cleaned by wrapping the silver in aluminium foil in hot water and baking soda. Use the reactivity series of metals to **determine** why this process works.

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

//SCIENCE AS A HUMAN ENDEAVOUR//

5.4 Green chemistry reduces the impact of chemicals on the environment

Learning intentions

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

- describe some green chemistry measures
- analyse and evaluate safety data.

Being 'green' means doing something positive for the environment. Scientists with special knowledge in ecology, biochemistry, zoology and botany study the environment and how it responds to changes. These scientists monitor the environment to detect changes caused by natural events and human actions.

Low-impact chemicals

Some chemicals have a negative impact on the environment and living things. When these substances are identified, scientists act to reduce their use and prevent them from entering the environment. Some substances are banned altogether.

New chemical products and processes are described as 'green' if they have less impact on the environment than the product or process they replace. The study and development of new substances that have a low impact on the environment is called 'green chemistry'.

Some examples of the development of 'green' alternatives are described below.

PESTICIDES AND HERBICIDES

Pesticides and herbicides have been used to kill organisms that eat our food crops and the plants that compete with these crops for sunlight and nutrients. In the past, some of these products killed all living things, not just the target species. Most were non-degradable (did not break down) and remained in the environment long after they were no longer needed. These substances are now banned and have been replaced with **biodegradable** poisons.

biodegradable describes an object or a substance that can be broken down by bacteria, fungi or other living organisms

In many cases, chemical poisons have been replaced with new farming practices, such as crop rotation and planting pest-resistant crop varieties.

HEAVY METALS

Heavy metals include lead, mercury and cadmium. Heavy metals had many uses, especially in dyes, and were used in chemical processes as catalysts. But these metals accumulated in the bodies of living things, including people. The most dramatic example of poisoning occurred in 1956 when people in Minamata, Japan were poisoned by mercury after eating contaminated seafood.

The use of heavy metals in situations where they could enter the environment has been largely stopped. Heavy metals have been replaced with different catalysts and production processes have changed.

SOLVENT-BASED PAINTS

Acrylic paints have slowly replaced solvent-based enamel paints and lacquers. The solvent used in the old paints was a hydrocarbon, such as turpentine, and it evaporated as the paint dried. The hydrocarbon solvents in enamel paint were toxic to aquatic life in waterways and the fumes from the paint caused 'painter's disease' in the workers who inhaled them.

Solvent-based paints have been replaced with acrylic paints, which are water based and set by polymerisation of the paint, not by evaporation of a solvent.

Circular economy

Understanding how particular chemicals can affect the environment means that chemical engineers can work with designers to maximise recyclability of products, and to minimise the amount of landfill that is produced with new product.

This process of planning the life cycle of all components of a product, including planning to eliminate waste and pollution, circulating materials and regenerating nature, is part of the **circular economy**.

circular economy
an economic system where materials are reused and recycled rather than used and disposed of

The cosmetic company Lush joined the circular economy when it redesigned some of its personal care products so that they could be sold as solids. Their shampoos, conditioners and deodorants no longer need plastic bottles, reducing the amount of plastic in the environment.

Other companies such as IKEA are developing alternatives to plastic packaging for their products. Using recycled materials that have similar properties (such as shock absorbance) reduces landfill and increases the circular economy.

How you can help

You can help protect the environment and the planet by adopting the slogans ‘reduce, reuse, recycle’ and ‘act local, think global’ to reduce your footprint on the environment. You can:

> use your own shopping bags instead of plastic bags
> compost grass clippings and food scraps and use the compost as fertiliser instead of using chemical fertilisers
> use trigger-action spray bottles, not aerosols
> avoid non-degradable products, such as some biocides
> leave the car at home for short journeys and take public transport or ride a bike instead
> use natural cleaning products and avoid chlorine-based cleaners.

a

b

Figure 1 There are many ways you can reduce your impact on the environment, such as **a** using trigger spray bottles instead of aerosols and **b** walking instead of driving.

5.4 Test your skills and capabilities

Personal and environmental safety

Before new agricultural or veterinary chemicals that contain a new active ingredient can be produced or imported into Australia, they must first be approved for use by the Australian Pesticides and Veterinary Medicines Authority (APVMA) to make sure that they satisfy safety, trade, efficiency and labelling criteria. The information that needs to be provided may be the results of scientific experiments or a comparison to an existing chemical that is already in use.

1 A chemical manufacturer would like to import a herbicide (substance that kills plants) that has the active ingredient diquat dibromide monohydrate. As a scientist working for the APVMA, you are responsible for preparing recommendations for or against the importation of new products.

Write a recommendation with evidence to support your decision by:

> using the Safety Data Sheet (SDS) for this product (which can be found by searching the internet) to **describe** the chemical’s toxicity to:
  a humans
  b animals
  c the environment.
> **describing** how this active ingredient is currently used in Australian agriculture
> **describing** how and why this chemical is used or not used in the European Union
> outlining your decision for or against the importation of the new product.

CHAPTER 5 REVIEW

CHEMICAL REACTIONS

Retrieve

1 **Identify** each of the following statements as either true or false.
   a Reactants are the substances made in chemical reactions.
   b Atoms cannot be created or destroyed.
   c An ore is a concentrated mineral.
   d Metals at the top of the reactive series of metals are more reactive.

2 **Recall** the general equation for the following chemical processes used in isolating a metal.
   a roasting
   b smelting
   c reduction

3 **Recall** the cause of Minamata disease.

4 **Name** the main element found in the mineral bauxite.

Figure 1 Bauxite

5 **Define** 'circular economy'.

Comprehend

6 The reactants in the production of carbon dioxide and salt by mixing sodium bicarbonate and vinegar are:
   A carbon dioxide and vinegar
   B carbon dioxide and salt
   C sodium bicarbonate and salt
   D sodium bicarbonate and vinegar.

7 The products in the production of carbon dioxide and salt by mixing sodium bicarbonate and vinegar are:
   A carbon dioxide and vinegar
   B carbon dioxide and salt
   C sodium bicarbonate and salt
   D sodium bicarbonate and vinegar.

8 **Represent** the following reactions as word equations.
   a Most gas stoves burn methane with the oxygen in air to produce carbon dioxide and water.
   b The mixing of vinegar (acetic acid) and marble (calcium carbonate) produces bubbles of carbon dioxide, water and calcium acetate.
   c Carbon dioxide and water are produced when wood is burned with oxygen.

9 **Describe** the the meaning of the 'law of conservation of mass' in your own words.

10 **Describe** the process of electrolysis.

Analyse

11 **Identify** which of the following is a balanced equation.
   A $CH_4 + O_2 \rightarrow CO_2 + 2H_2O$
   B $CH_4 + 2O_2 \rightarrow CO_2 + H_2O$
   C $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
   D $CH_4 + O_2 \rightarrow 2CO_2 + 2H_2O$

12 Write a balanced chemical equation for the reaction below. Mercury oxide (HgO) is heated, its atoms rearrange to form mercury liquid (Hg) and oxygen gas (O_2).

Figure 2 Liquid mercury

13 **Identify** the number of atoms of carbon, hydrogen and oxygen in a molecule of ethanol (CH_3CH_2OH).

14 Balance the following equations.
   a $CO_2 + H_2O \rightarrow C_6H_{12}O_6 + O_2$
   b $SiCl_4 + H_2O \rightarrow H_4SiO_4 + HCl$
   c $Al + HCl \rightarrow AlCl_3 + H_2$
   d $Na_2CO_3 + HCl \rightarrow NaCl + H_2O + CO_2$
   e $C_7H_6O_2 + O_2 \rightarrow CO_2 + H_2O$
   f $KClO_3 \rightarrow KClO_4 + KCl$

15 **Consider** the reactions that occur as the following chemicals interact with each other:
   a iron filings (Fe) in in hydrochloric acid (HCl) to produce hydrogen gas (H_2) and iron chloride ($FeCl_2$)
   b carbon dioxide (CO_2) dissolves in water (H_2O) to form a solution of carbonic acid (H_2CO_3).

   For each situation, **describe** the reaction as:
   i the reactants and products
   ii a word equation
   iii a balanced chemical equation.

16 **Identify** the method that could be used to separate a very dense metal from its ore.

17 **Compare** a cathode and an anode in electrolysis.

18 **Identify** two examples of green chemistry that you could apply at home.

Apply

19 Smithsonite is an ore that contains high levels of zinc carbonate.

  a The mineral is concentrated using froth flotation and leaching. **Describe** these processes.

  b **Propose** how the zinc could be isolated from its mineral.

  c **Describe** some of the uses of zinc metal.

Figure 3 Smithsonite

Critical and creative thinking

20 **Create** a poster that outlines how to balance the chemical reaction below.

$$H_2SO_4 + HI \rightarrow H_2S + I_2 + H_2O$$

21 **Create** a poster that outlines the extraction and purification process of producing copper.

22 **Conduct** a PNI ('positive', 'negative', 'interesting') analysis on the effect of plastics on our lives.

Table 1 The effects of plastics on our lives

Positive	
Negative	
Interesting	

23 Some supermarkets have started producing biodegradable bioplastic bags from cornflour. **Evaluate** the impact of using corn to produce plastic (by defining the term 'biodegradable', explaining the effect of growing extra corn on the environment and potential land clearing, explaining the effect of using non-biodegradable plastic bags on the environment and deciding which impact causes the least harm).

Figure 4 Biodegradable plastic bags

24 **Evaluate** the following statement.
'An important part of mining is the reclamation of the environment when the amount of metal ore is no longer worth the cost of extraction, concentration, isolation and purification.'

Figure 5 The Mary Kathleen uranium mine in western Queensland closed in 1982.

Social and ethical thinking

25 The mining of metals can have a significant effect on the environment. Consider the effect of mining metals such as copper, silver, silicon and zinc that are needed to make solar panels. **Discuss** the views of each of the people below.

  a the miner extracting the ore

  b the farmer whose land is being mined

  c the person who wants to reduce greenhouse gases

Research

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

» Phosphoric acid

Phosphoric acid has a wide variety of uses, including as a fertiliser, rust remover and food additive. It is even an ingredient of cola drinks. Describe how it is produced and more about its uses.

Figure 6 Phosphoric acid is used to produce many products, such as fertiliser.

» Rare metals

A range of rare metals is used in microelectronic devices. Many of these metals, such as tantalum and niobium, are sourced from Australia.

- Identify where these metals are found in Australia.
- Identify the chemical name of the mineral in which these metals are found.
- Describe the chemical processes that are used to extract the pure metal.

Figure 7 Niobium

» Explosives

The history of the development of explosives is fascinating.

- Identify the person who discovered them.
- Describe when explosives were first used and how they work.
- Identify the main chemicals used and the different types of these chemicals.
- Explain the part Alfred Nobel played in the development of explosives.

Figure 8 Explosive device being tested in an isolated area

» Carbon footprints

- Describe what is meant by the phrase 'carbon footprint'.
- Identify the chemical reactions that contribute to an increase in carbon dioxide in the atmosphere.
- Identify the other gases that contribute to the enhanced greenhouse effect.
- Describe how carbon footprints are measured.
- Describe what is meant by the phrase 'carbon offset'.

Figure 9 Our actions have an effect on the environment.

Chapter checklist

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

	I can do this.	I cannot do this yet.
• Identify the reactants and products in a chemical reaction. • Explain and apply the law of conservation of mass.	☐	☐ Go back to Topic 5.1 'Mass is conserved in a chemical reaction'. Page 96
• Describe a chemical reaction. • Write, balance and assign states to chemical reactions.	☐	☐ Go back to Topic 5.2 'Balanced chemical equations show the rearrangement of atoms'. Page 98
• Describe processes used to concentrate minerals and isolate metals. • Use the reactivity series of metals to explain phenomena.	☐	☐ Go back to Topic 5.3 'Chemical reactions are used to purify elements from ore'. Page 100
• Describe some green chemistry measures. • Analyse and evaluate safety data.	☐	☐ Go back to Topic 5.4 'Science as a human endeavour: Green chemistry reduces the impact of chemicals on the environment'. Page 104

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Quizlet
Play a Quizlet game to test your knowledge.

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

CHAPTER 6

THE CARBON CYCLE

6.1

The Earth's spheres are balanced

- Identify the differences between the lithosphere, atmosphere, hydrosphere and biosphere.
- Explain how the spheres interact with one another.

6.2

Carbon cycles through Earth's spheres

- Explain the main processes involved in the carbon cycle.
- Explain the processes involved in photosynthesis.
- Identify the reactants and products of photosynthesis and cellular respiration, and describe why they are not reversible versions of each other.

6.3 Human activity affects the carbon cycle

- Explain how matter moves through the carbon cycle and identify the key participants.
- Apply the carbon cycle to explain a carbon sink.
- Identify and describe the impact that humans have on the carbon cycle.

6.4 Traditional knowledge reduces carbon emissions

- Contrast hazard reduction burning and cultural burning.
- Describe how First Nations knowledge and the practice of cultural burning can reduce carbon emissions.

6.5 Evidence supports the enhanced greenhouse effect

- Explain the trend in increased temperature over time.
- Explain why greenhouse gas concentrations in the atmosphere are rising.

6.6 Science as a human endeavour: Humans can reduce the effects of climate change

- Describe the importance of the Kyoto Protocol.
- Explain how greenhouse gas emissions can be reduced by humans.

What if?

Increased sea levels

What you need:

Map of local coastal areas with height above sea level marked or highest astronomical tide marked, map showing local food-growing regions

What to do:

Compare the two maps. What do you notice about the areas that are at risk of current high tides?

What if?

- What if the high-tide line was to increase by 1 m? (Would your home be at risk?)
- What if the high-tide line was to increase by 5 m? (Would food-growing regions be at risk?)

6.1 The Earth's spheres are balanced

Learning intentions

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

- identify the differences between the lithosphere, atmosphere, hydrosphere and biosphere
- explain how the spheres interact with one another.

Key ideas

- The Earth is made up of the lithosphere (solid crust), atmosphere (air), hydrosphere (water) and biosphere (living organisms).
- Interaction between the Earth's spheres maintains global temperatures and climate.

Interactive 6.1A
Atmosphere

Interactive 6.1B
Classifying components of the Earth

lithosphere
the outermost layer of Earth, consisting of the upper mantle and crust

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

atmosphere
the layer of gases surrounding the Earth

The solid crust of the Earth (lithosphere) interacts with the atmosphere (air) and hydrosphere (solid, liquid and gaseous water) to influence temperature and therefore the climate in mountains and deserts, as well as the ocean currents. In return, these three spheres affect all the living organisms in the biosphere. A balance must be maintained to ensure the survival of all life on this planet.

The lithosphere

The outermost rocky layer of the Earth is the **lithosphere**. It is made up of the upper mantle and the crust (Figure 1). Although the crust and upper mantle are approximately 80 km thick, at the scale of the Earth they actually form a very thin layer.

The rocky crust of the Earth is made from magma (molten rock), which cools very slowly and at different times all over the surface of the Earth.

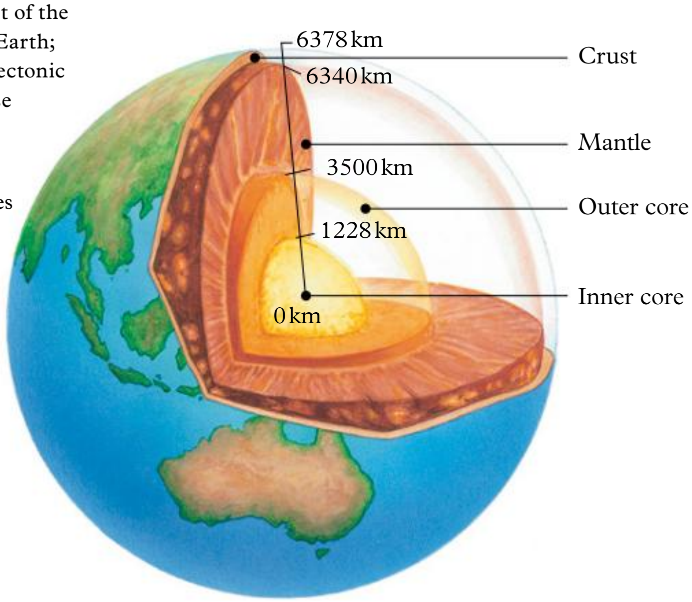


Figure 1 The Earth is made up of layers.

The heat from the magma escapes into the air and water surrounding it. The cooled crust settles as uneven giant plates of rock that are mismatched and butt up against their neighbours, covering the entire Earth. The giant pieces are called **tectonic plates**. These plates float on the semi-liquid magma at the top of the mantle. The heat in the mantle creates currents that slowly stir through the molten rock, moving the tectonic plates as well. The tectonic plates move about 2–10 cm per year – a similar rate to the growth of your fingernails.

The lithosphere is the slowest of Earth's systems to change. Small changes can take thousands, even millions, of years.

The atmosphere

The **atmosphere** is a layer of gases that we commonly call air (Figure 2). The atmosphere is relatively thin compared to the size of the Earth: if the Earth were the size of a party balloon, the atmosphere would only be as thick as the rubber skin of the balloon.

The Earth is the only planet in our solar system that has an atmosphere that sustains life. It helps keep us warm, controls our weather, protects us from the dangers from space and carries sounds.

The most important gas for humans and other animals is oxygen (O_2), which makes up 21 per cent of the atmosphere. Oxygen in the Earth's atmosphere allows organisms to respire. Other gases in the atmosphere include ozone (O_3), which offers protection from the Sun's UV radiation; carbon dioxide (CO_2); water (H_2O) and other greenhouse gases, which trap heat to keep us warm; and nitrogen (N_2), which makes up 78 per cent of the atmosphere.

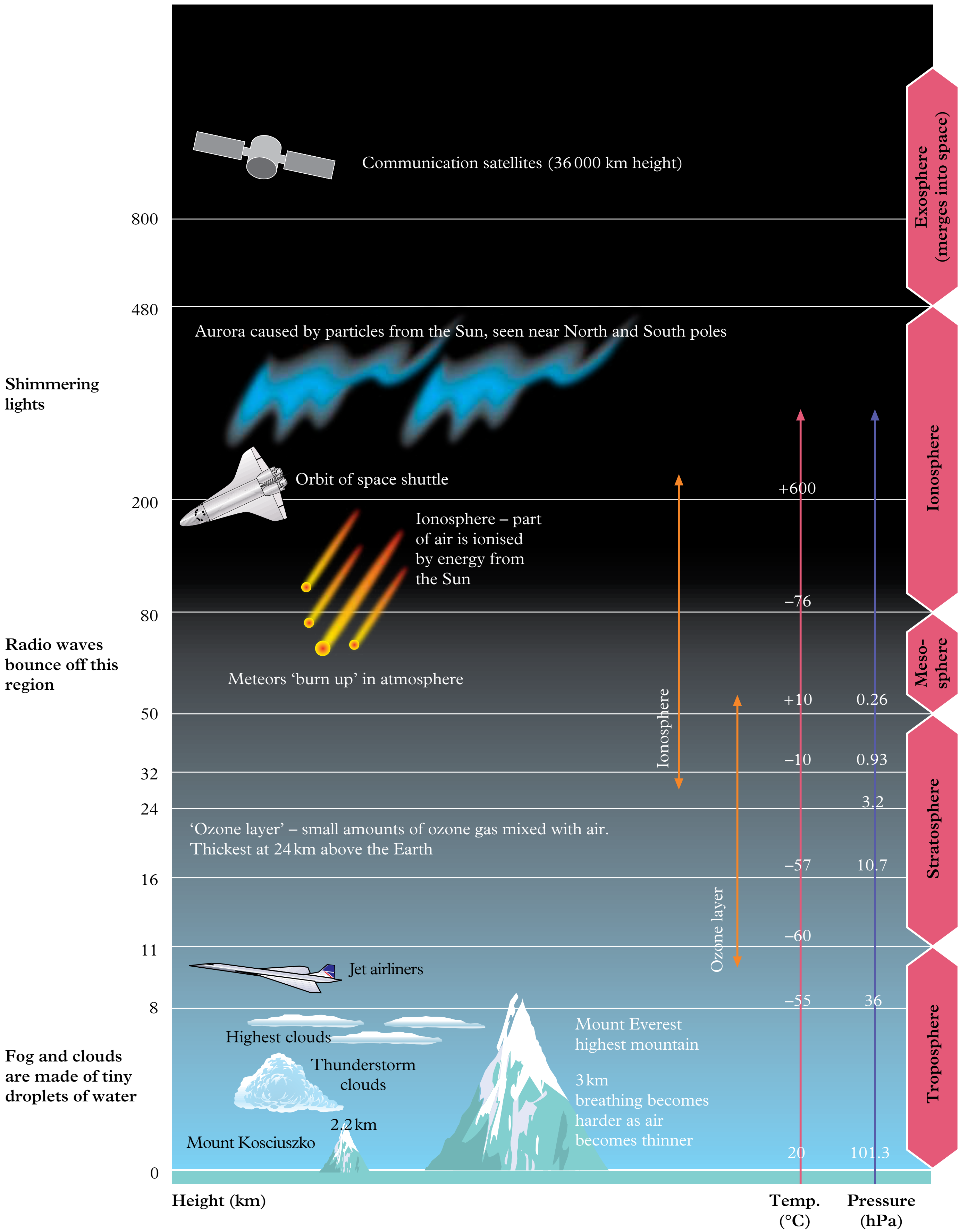


Figure 2 Each layer of the Earth's atmosphere has different characteristics.

Layers in the atmosphere

The atmosphere is more dense at ground level and thins out as you go higher above the Earth's surface: 99 per cent of all the air in the atmosphere is found within 80 km of the Earth's surface. There is not really a top to the atmosphere – the air just thins out, with decreasing pressure, until you reach the relative emptiness of space. These changing conditions are identified as several atmospheric layers (Figure 2).

The hydrosphere

The **hydrosphere** is made up of all the Earth's water – oceans and lakes, but also the water in glaciers, the soil and even in the air (Figure 3). The hydrosphere covers approximately 70 per cent of the Earth's surface, making the Earth the 'blue planet' when viewed from space. The huge amount of water, in all its various forms, is also home to many types of plants and animals. The hydrosphere interacts with and is influenced by each of the other spheres. The heat from the lithosphere warms the atmosphere and hydrosphere, allowing the production of water in three different states: liquid, vapour and solid (glaciers and ice).

The hydrosphere influences climate

The part of the hydrosphere that is made up of frozen water is called the **cryosphere**. The cryosphere is very important in regulating the climate on the Earth and the amount of nutrients in the ocean. When the ice melts, it produces very dense cold water that sinks to the bottom of the ocean disturbing the nutrients on the ocean floor. As the icy water is carried away by the current, it slowly warms and lifts the nutrients to the surface, where it starts the ocean's food chain. As the current travels north, the atmosphere heats the water, causing it to evaporate and affect the climate.

The biosphere

The **biosphere** is made up of all the living things on the Earth, including plants, animals and bacteria. Within this sphere, there is an enormous degree of organisation and an amazing variety of different types of organisms (**biodiversity**; *bio* = life, *diversity* = variety). Each organism is interdependent with others; the survival of each species is dependent on other species. The biosphere needs to maintain a careful balance.

The Earth is the only planet in our solar system that can support a biosphere. Although life could exist in all spheres on the Earth, most living things can only survive in a fairly narrow range of conditions – from deep under the ocean to high in the mountains.

hydrosphere
all the solid, liquid and gaseous waters on Earth that support life

cryosphere
the frozen water in the hydrosphere

biosphere
a layer around the Earth's surface that supports life; consists of the atmosphere, hydrosphere and lithosphere

biodiversity
the variety of life; the different plants, animals and mircroorganisms and the ecosystems they live in

Figure 3 All the Earth's water makes up the hydrosphere.

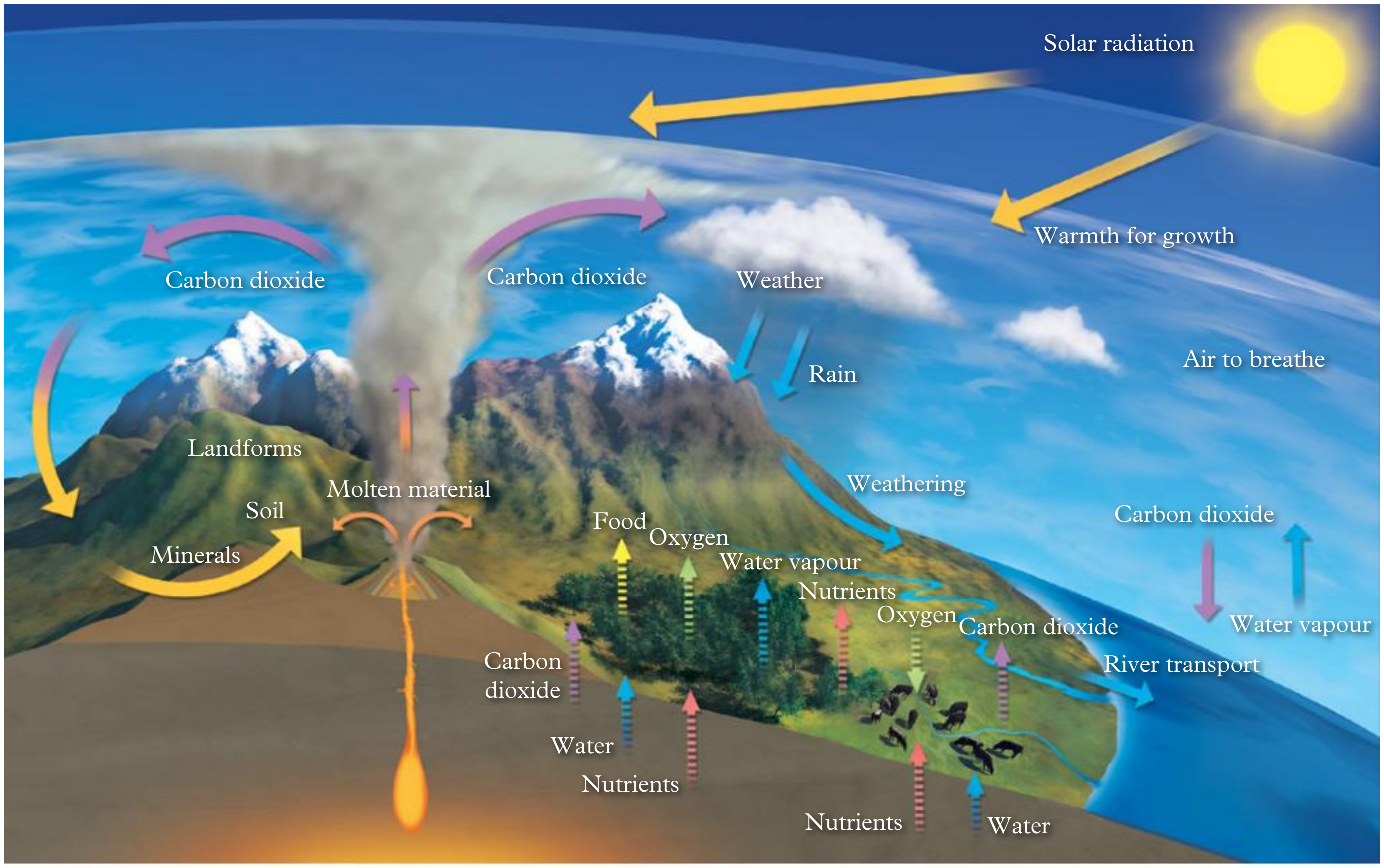


Figure 4 The inputs and outputs of the Earth's living and non-living systems

Figure 5 Volcanoes are part of the lithosphere.

6.1 Check your learning

Retrieve

1 **Define** the term 'biosphere'.

2 **Identify** the layer of the atmosphere in which we live.

Comprehend

3 **Describe** the different elements that make up the lithosphere.

4 **Describe** what happens to the amount of air as you go higher into the atmosphere.

5 **Explain** how the hydrosphere interacts with the other spheres.

Analyse

6 **Compare** the hydrosphere and the cryosphere.

Apply

7 **Create** a Venn diagram with four interlocking circles, one for each of the spheres studied. **Label** each sphere and include all the features they share.

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

6.2 Carbon cycles through Earth's spheres

Learning intentions

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

- explain the main processes involved in the carbon cycle
- explain the processes involved in photosynthesis
- identify the reactants and products of photosynthesis and cellular respiration, and describe why they are not reversible versions of each other.

Key ideas

- The carbon cycle describes how carbon atoms cycle through an ecosystem.
- Photosynthesis removes carbon dioxide from the atmosphere.
- Carbon trapped in the lithosphere cycles very slowly, whereas carbon in the biosphere and atmosphere cycles much faster.
- Carbon can be stored in carbon sinks such as fossil fuels and the ocean.

Cycles of matter

Matter cannot be created or destroyed. This means matter must be recycled. The cycling of matter from the atmosphere or the Earth's crust and back again is called a biogeochemical cycle (*bio* means 'living'; *geo* means 'earth').

Carbon is the fourth most abundant element on Earth.

All life on Earth is considered a 'carbon-based life form' because many of the key chemical molecules that are essential to life (including DNA, carbohydrates, proteins and lipids) contain carbon atoms. Because carbon atoms cannot be created or destroyed, they must be continually cycled through the land, oceans and atmosphere of Earth's global systems (Figure 1).

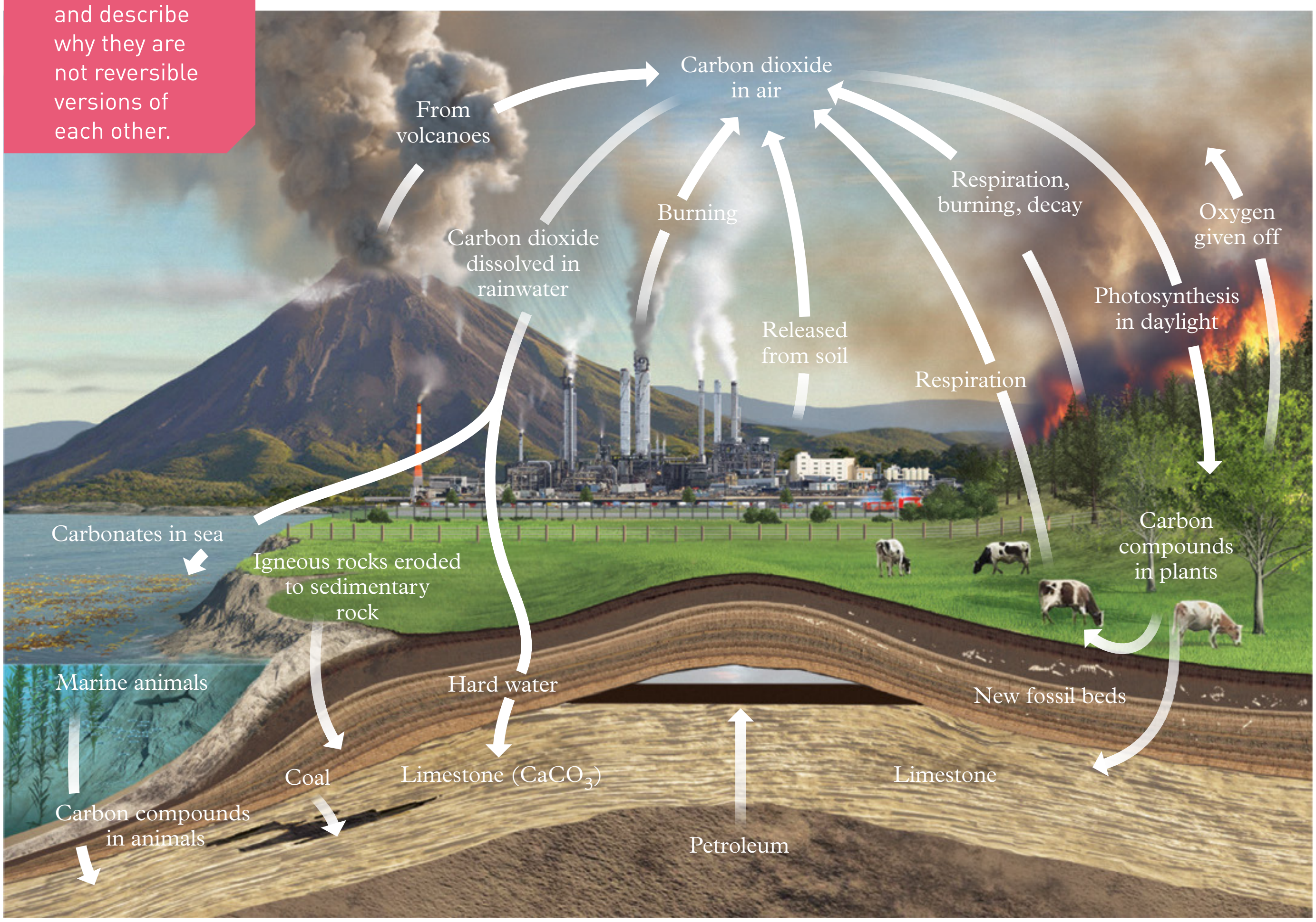


Figure 1 The carbon cycle

CHALLENGE

6.2: Modelling a carbon sink
Go to page 201.

The carbon cycle

Carbon atoms circulate in and around all living things. These important atoms exist in all of Earth's spheres from the carbonate molecules in limestone to the petroleum in the fossil beds, from carbohydrates in plants to the proteins that help animals move. The way carbon cycles can be divided into two cycles depending on the length of time it takes to change its form.

> The geological carbon cycle is a long-term cycle that occurs over hundreds to millions of years and has resulted in the bulk of carbon being locked in rocks or in sediments as fossil fuels.

> The biological/physical carbon cycle is a short-term cycle that occurs over days, weeks, months and years, and it involves the cycling of carbon through photosynthesis and cellular respiration.

When describing the carbon cycle, one of the starting points used is the carbon dioxide in the air. Explaining how the carbon in the air enters and leaves the organic carbon molecules found in living things helps us to understand the complexity of the carbon cycle.

Photosynthesis

Living things need energy to grow and repair, to defend themselves, and to move around. The energy in an ecosystem usually originates from the Sun. Plants, some algae and some bacteria are able to transform this light energy into chemical energy. Carbon is an important part of this process. The light energy of the Sun enables the plants to capture the carbon dioxide from the air. This carbon dioxide (CO_2) then chemically reacts with water (H_2O) to produce a carbon-based molecule called glucose ($C_6H_{12}O_6$), and oxygen (O_2) through a process called **photosynthesis**.

The overall equation for photosynthesis is:

carbon dioxide + water → glucose + oxygen + water

$$6CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$$

Plants use the carbon, hydrogen and oxygen in glucose to make other structural molecules such as proteins, lipids and complex carbohydrates. These molecules are used to produce new leaves, roots and stems so that a plant can grow and repair itself.

One of the most common uses for the glucose is a chemical reaction that produces the energy needed to survive.

When an animal eats a plant, it can use the carbon-based molecules in a chemical reaction called **cellular respiration**.

Figure 2 Plants use energy from the Sun to grow and repair.

Cellular respiration

Cellular respiration is similar to burning. Whenever we burn a fuel, such as wood or oil, we release the carbon that has been chemically stored in the molecules of the once living organism. The carbon in the fuel molecules is organised, or ordered, because it is bound in the molecule. Burning requires oxygen and is a rapid process, releasing the energy as heat energy. Carbon dioxide and water are also produced.

Cellular respiration is more organised and controlled than burning. Glucose is the molecule that our body uses for fuel. Each cell uses oxygen to 'burn' glucose and convert the energy into ATP (adenosine triphosphate). ATP is much easier for our bodies to use for energy. The carbon in fats and proteins can also be converted into ATP in cellular respiration.

Oxygen is used during cellular respiration, and carbon dioxide and water are waste products. Because oxygen is needed for this process, it is called **aerobic cellular respiration**.

The general equation for aerobic cellular respiration is:

Reactants / Products

glucose + oxygen → carbon dioxide + water + energy

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 36ATP$$

The carbon stored in the glucose is released into the air as carbon dioxide.

matter
anything that has space and volume; matter is made up of atoms

photosynthesis
a chemical process used by plants to make glucose and oxygen from carbon dioxide, sunlight and water

cellular respiration
chemical reaction that transfers energy to cells

aerobic cellular respiration
a chemical reaction between glucose and oxygen to produce carbon dioxide, water and energy

Photosynthesis and respiration

The reactants and products of photosynthesis and cellular respiration are almost mirror images of one another. The reactants of one are the products of the other. The main difference is that photosynthesis uses energy from the Sun, while cellular respiration produces chemical energy (ATP) rather than light energy. Photosynthesis traps carbon dioxide in the air, converting it into carbon-rich glucose. Cellular respiration moves the carbon out of glucose and into carbon dioxide, which is then released back into the air. Many of the molecules in the two reactions are the same, but they are part of different pathways. Glucose is a product of photosynthesis, whereas it is a reactant in cellular respiration.

Globally, the return of carbon dioxide to the air by cellular respiration is balanced by its removal in photosynthesis. Other ways of returning carbon dioxide to the air include the burning of fossil fuels, bushfires and the decomposition of dead matter. The natural balance of this cycle is disturbed by excess burning, which contributes to the **enhanced greenhouse effect**.

enhanced greenhouse effect
an increase in carbon dioxide and other heat-capturing gases in the atmosphere, resulting in increased warming of the Earth

carbon sink
any feature of the environment that absorbs and/or stores carbon

Storing carbon

Carbon is stored over the long term in the trunks and branches of trees. It is also temporarily stored in the bodies of other organisms, such as herbivores and carnivores. When these organisms die, carbon is returned to the atmosphere through cellular respiration by bacteria and fungi (decomposers).

A **carbon sink** is any feature of the environment that absorbs and/or stores carbon, keeping it from the atmosphere. Forests take in carbon dioxide for photosynthesis and use it to grow stems and leaves, so they are a very significant carbon sink.

Figure 3 Forests are an example of a carbon sink.

Figure 4 A termite mound in the savannah of northern Australia

However, the ability of forests to absorb carbon has been reduced as a result of the large-scale clearing of forests throughout the world.

Termites recycle carbon

Plant cell walls are made of cellulose, a complex carbohydrate that is insoluble in water and does not break down easily. Fungi are able to break down cellulose and play a major role in the decomposition of wood, but they require a moist environment, like that in a rainforest. In drier areas of Australia, such as forests and woodlands in tropical and subtropical areas, as well as savannah grasslands, termites have a major role in the decomposition and recycling of carbon.

Termites are social insects and live in nests. You may have seen termite mounds in drier parts of Australia (Figure 4). Microorganisms in the guts of termites break down the cellulose of plant material such as grasses, plants and wood. Scientists have estimated that termites recycle up to 20 per cent of the carbon in ecosystems such as savannah grasslands.

Ocean acidification

The ocean is another important carbon sink. Carbon dioxide is able to dissolve in the ocean water. An unfortunate consequence of this is the production of carbonic acid. This process is called **ocean acidification**.

water		carbon dioxide		carbonic acid
H_2O	+	CO_2	$\rightarrow$	H_2CO_3

Although carbonic acid is a weak acid, it can affect the survival of reefs and ocean creatures that have shells made of calcium carbonate ($CaCO_4$). The carbonic acid reacts with the shells of many molluscs, causing them to become thin (Figure 5).

Figure 5 Mollusc shells become thin when exposed to carbonic acid.

Oceans are not the only sites that store carbon. It is also stored in:

- decomposed organic matter, such as coal, natural gas, petroleum and shale oil
- rocks, such as limestone, marble, dolomite, chalk and other carbonates
- organic matter in the soil
- dissolved carbon dioxide in other waters
- the shells of marine organisms and some terrestrial organisms.

All of these carbon sinks will release carbon if the environmental conditions change.

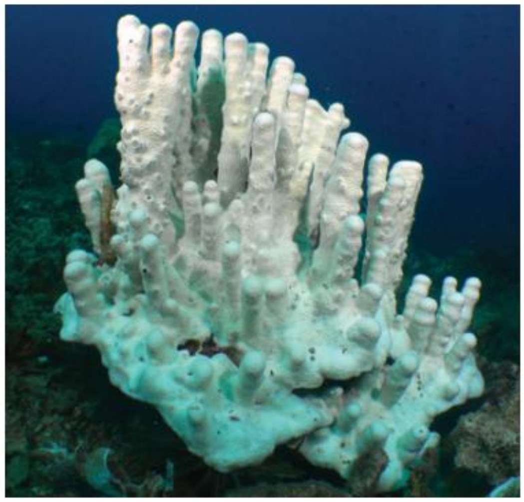


Figure 6 Increased carbon dioxide levels in the atmosphere cause the ocean to become acidic. As a result, the polyps in the coral die, causing bleaching.

ocean acidification
the production of carbonic acid in the ocean due to the absorption of carbon dioxide

6.2 Check your learning

Comprehend

1 **Describe** how matter moves through an ecosystem.

2 **Explain** what is meant by the term 'carbon cycle'.

3 **Describe** three ways carbon dioxide can be released into the environment.

4 **Describe** two ways carbon dioxide can be removed from the atmosphere.

Analyse

5 **Contrast** the geological carbon cycle and the biological/physical carbon cycle.

6 **Compare** cellular respiration and photosynthesis.

7 **Infer** why cellular respiration is constantly occurring in cells (by identifying the key product of the reaction and what the organism uses this molecule for).

Apply

8 'You are eating the same atoms that were in dinosaur poo!'
Evaluate the accuracy of this statement (by describing how matter moves through an ecosystem, describing how the atoms in dinosaur poo will change over time and deciding whether the statement is correct).

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

6.3 Human activity affects the carbon cycle

Learning intentions

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

- explain how matter moves through the carbon cycle and identify the key participants
- apply the carbon cycle to explain a carbon sink
- identify and describe the impact that humans have on the carbon cycle.

Key ideas

- Combustion reactions use fuel and oxygen to produce heat and water.
- The use of fossil fuels (petrol and oils) releases carbon into the atmosphere.
- Increasing agriculture can disrupt the carbon cycle.

Releasing carbon dioxide

Humans tap into the geological carbon cycle by extracting oil, natural gas and coal (all of which are hydrocarbons) for use in cars and energy production. Large-scale extraction and the burning of these fossil fuels has resulted in increased levels of carbon dioxide in the atmosphere.

When you see something burn, you are witnessing a substance reacting with oxygen in a chemical reaction. The amount of energy released in this reaction can be huge. It is in the form of heat energy and light energy – which we see as a flame – and sometimes sound energy as well. The products of these reactions are always carbon dioxide and water.

What happens when fuels burn?

In science, a **fuel** is a substance that will undergo a chemical reaction in which a large amount of chemical energy is produced at a fast but controllable rate. We use fuels such as the methane in natural gas to produce heat and/or electricity, and fossil fuels to run engines and motors.

When a fuel reacts in the presence of oxygen, it is called a **combustion reaction**. These reactions produce heat and water.

Hydrocarbons are very common fuels that only contain the elements hydrogen and carbon. When hydrocarbons burn in unlimited air, carbon dioxide and water are produced. Petrol, diesel and LPG are all hydrocarbons.

hydrocarbon fuel + oxygen → carbon dioxide + water vapour + lots of energy

When the oxygen supply is more limited, for example when a candle burns in a poorly ventilated space, less heat energy is released and poisonous carbon monoxide gas is produced. Carbon monoxide can be deadly: it replaces the oxygen in our blood, which can kill us.

hydrocarbon fuel + limited oxygen → carbon monoxide (poisonous) + water vapour + some energy

Figure 1 Burning coal produces carbon dioxide.

Figure 2 Bushfires are an important part of the carbon cycle, releasing carbon back into the atmosphere.

fuel
a substance that undergoes a chemical reaction producing large amounts of energy

combustion reaction
a reaction between a fuel and oxygen that produces heat and water

hydrocarbon
a molecule that contains only carbon and hydrogen atoms

CHALLENGE

6.3: Combustion and candles
Go to page **202**.

Changing carbon cycle

As the human population has increased, the balance between new growth plants and old growth plants has been disrupted. This has interrupted many parts of the carbon cycle. For example:

- Freshwater ecosystems have been altered through the building of dams for irrigation and hydroelectric power production, resulting in whole landscapes decomposing under water.
- Agriculture has converted more than half the world's many woodlands for human use, releasing the carbon stored in slow growth trees.
- Farming livestock such as cattle and pigs has increased the number of animals releasing methane (CH_4) into the atmosphere.

Australian bushfires

The increased number and intensity of bush fires has also had an impact on the amount of carbon dioxide in the air.

Carbon stored in old slow growth bush becomes the fuel in a bushfire, producing carbon dioxide as well as methane, carbon monoxide and smoke (solid carbon particles).

This was most obvious in the 2019–2020 Australian bushfires that burnt more than 143 000 square kilometres. During this time, scientists took daily pictures that measured the amount of carbon monoxide levels in the atmosphere. This was used to estimate that the amount of carbon dioxide released into the atmosphere during this period was 250 million tonnes.

The plumes of smoke produced during this event were tracked thousands of kilometres over the ocean and eventually mixed in the waters of the Southern Ocean. The nutrients in this smoke (including carbon) provided nutrients that allowed small organisms called phytoplankton to rapidly increase their population. This 'bloom' of phytoplankton provided a rich food source for the marine food web in that part of the ocean.

Figure 3 Bushfires release large amounts of carbon dioxide into the atmosphere.

6.3 Check your learning

Retrieve

1 **Identify** the two elements that are in hydrocarbons.

2 **Recall** the products of a hydrocarbon combustion reaction.

3 **Recall** the products of a hydrocarbon combustion reaction where oxygen is limited.

Comprehend

4 **Describe** two ways human activity affects the carbon cycle.

5 The fuels used in cars, trucks and buses are generally liquefied petroleum gas (LPG), petrol or diesel. These fuels are mainly hydrocarbons. **Explain** why scientists are warning that excessive use of these vehicles is contributing to the enhanced greenhouse effect.

Apply

6 **Consider** your response to question 5 and use the internet to **identify** one argument for and one argument against the use of petrol cars in Australia. **Evaluate** each argument (consider the reasoning and evidence behind them).

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

6.4 Traditional knowledge reduces carbon emissions

Learning intentions

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

- contrast hazard reduction burning and cultural burning
- describe how First Nations knowledge and the practice of cultural burning can reduce carbon emissions.

Key ideas

- Hazard reduction burning is the large-scale burning of all plants in an area.
- Cultural burning uses cooler flames to burn small selected parts of the landscape.
- Cultural burning increases carbon storage and maintains key indigenous plants and animals.

As the climate has changed over the last 50–100 years, the number and severity of bushfires has also increased. In the summer of 2019–2020, over 14.3 million hectares (143 000 square kilometres) of bushland and farming areas were burnt. Over 3000 buildings were destroyed, and it is estimated that over 3 billion animals were killed. Satellite images were used by NASA to estimate that over 250 million tonnes of carbon dioxide were produced as a result. This was 50 per cent of Australia's total carbon dioxide emissions in 2018.

A number of factors contributed to the severity of the bushfires. CSIRO identified one of the key factors as climate change. Increases in the average global temperatures have led to an increased number and severity of droughts. This causes the bushland areas to become drier and making them burn hotter and faster.

Uncontrolled bushfires rapidly burn plant matter and the dead leaves that can form the top part of the soil. This form of rapid combustion can lead to:

> loss of food and shelter for native animals
> erosion of the topsoil
> loss of infrastructure such as fences and buildings
> production of large amounts of carbon dioxide.

Many First Nations Australians have used fire as a tool to support the environment and to encourage the storage of carbon in the soil, especially in cooler forests, savannahs and grasslands. This traditional form of selective burning is called **cultural burning**.

cultural burning
the practice of burning vegetation used by Traditional Custodians of Country to enhance the health of Country; informed by deep knowledge of and relationship to Country

Cultural burning

Cultural burning is different from a hazard reduction burn. A hazard reduction burn is the targeted burning of bushland to reduce the amount of plant matter and materials that could contribute to a bushfire.

Its goal is usually to remove as much of these materials as possible. When this occurs, the plants, like non-native bracken, quickly regrow and rapidly reproduce. These plants have a short life cycle and contribute to the build-up of bushfire fuel within the next 1–2 years.

Cultural burning usually occurs in the cooler seasons and involves slow burning of small areas in the larger landscape. This encourages the longer-term growth of plants that are less flammable and slower to grow, reducing the build-up of bushfire fuel in the long term. Cultural burning maintains the number of trees and some areas of plants and grasses so that native wildlife has food and shelter immediately after the burn. It also protects key areas of human habitation and prevents the loss of animals and people. The smaller fire areas are much cooler than a hazard reduction burn. The seeds and roots in the soils are not damaged by the cooler fires, allowing them to quickly regrow.

Figure 1 Cultural burning involves selectively burning small areas of a landscape.

Cultural burning usually occur at the end of the wet season when the amount of fuel is low and before native seeds and fruits are ripe for harvest. Each ecosystem area will be different, and this is where local First Nations knowledge is important.

Most cultural burning is carried out during the night or early morning, when the low wind and presence of plant dew can help control the fire. The flames are deliberately kept cool and below knee height so that the tree canopy and tree bark are protected (Figure 2). It also helps the soil maintain moisture.

The cool ground fire burns slowly with less oxygen compared to a fire in the canopy of a tree. The leaves on a tree are surrounded by the oxygen-containing air.

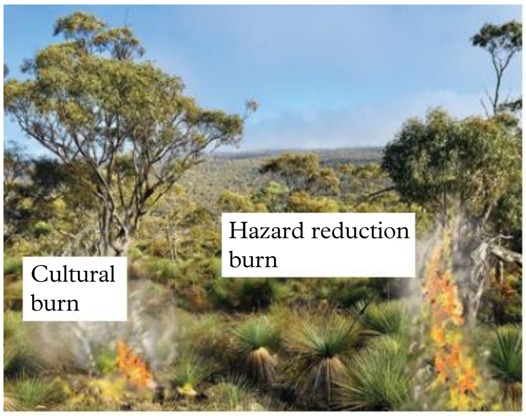


Figure 2 The difference between cooler cultural burning (left) and hot hazard reduction burning (right)

This large surface area allows the combustion reaction to occur faster, producing a lot more carbon dioxide than the slower ground burning.

West Arnhem Land

For more than 40 000 years, First Nations peoples have developed an understanding of the different landscapes in the Northern Territory and how they can be maintained. In 2004, scientists started working with the local people to develop a way to control the late season wild bushfires that were destroying up to one third of West Arnhem Land each year.

Over seven years (2005–2011), the First Nations peoples of West Arnhem Land worked with scientists to re-establish cultural burning practices early in the dry season. The program has been extended across Arnhem Land. Figure 3 shows that as the number of early season cultural burns with lower carbon dioxide emissions increased, the number of hot wildfires releasing large amounts of carbon dioxide decreased. This means that the cooler cultural burning is able to keep the carbon in storage for longer, reducing the amount of carbon dioxide contributing to increased global warming.

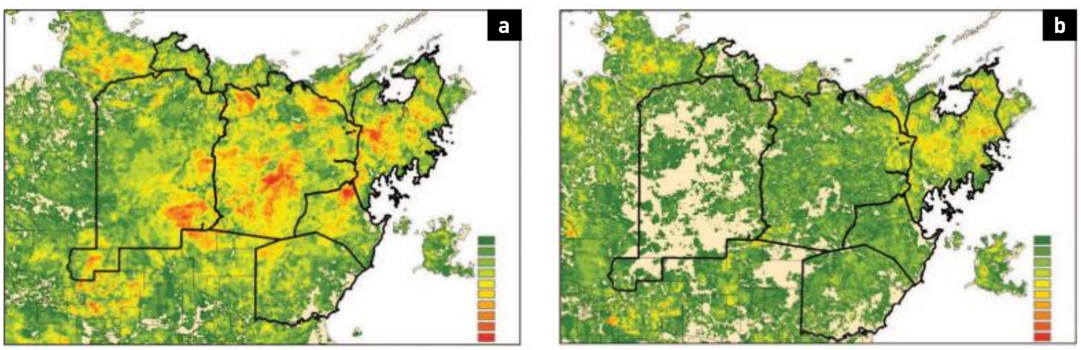


Figure 3 Early season cultural burning (green) reduces the number of late season wild bushfires (red). **a** The number of late season wild bushfires across Arnhem Land, 1995–2004, and **b** the reduced number of late season wild bushfires, 2008–2017, following cultural burning.

6.4 Check your learning

Retrieve

1 **Define** the term ‘cultural burning’.

Comprehend

2 **Describe** how bushfires damage an ecosystem.
3 **Describe** how a hazard reduction burn can harm the plants and animals in an ecosystem.
4 **Describe** the evidence that supports the theory that cultural burning reduces bushfires.
5 **Explain** how cultural burning reduces carbon emissions.

Analyse

6 **Contrast** hazard reduction burning and cultural burning.

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

6.5 Evidence supports the enhanced greenhouse effect

Learning intentions

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

- explain the trend in increased temperature over time
- explain why greenhouse gas concentrations in the atmosphere are rising.

Key ideas

- The Earth is surrounded by an atmosphere of natural greenhouse gases that reflect radiation from the Sun and retain the warmth from the Earth.
- Evidence for enhanced global warming can be found in the melting of sea ice and permafrost and increasing sea levels.

The Earth's climate has changed many times throughout history. These changes can take many thousands of years to slowly warm or cool the Earth and change the climate. A climate change event is occurring now: from dusty farms experiencing drought in the outback to families fleeing their homes in the worst flooding we have ever seen. This climate change is due to the enhanced greenhouse effect and is different from previous changes. It started during the Industrial Age (1850) and has increased the Earth's average temperature by 0.95°C since 1900. This short time period (100 years instead of 1000 years) does not allow time for living organisms (including humans) to adapt and evolve.

natural greenhouse effect the natural warming of the Earth due to water vapour and other gases being present in small amounts in the atmosphere and affecting the Earth's radiation balance

The greenhouse effect

The **natural greenhouse effect** is critical for maintaining life on Earth. Solar energy passes through the atmosphere and warms the Earth's surface.

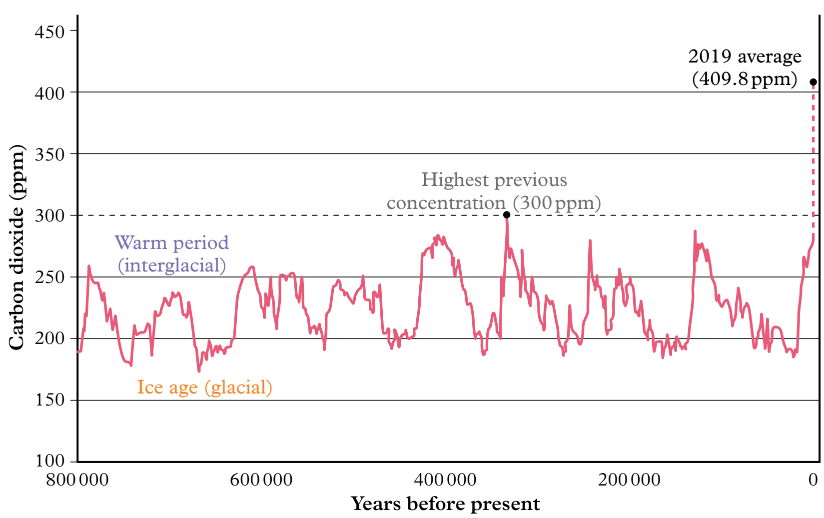


Figure 1 Carbon dioxide levels in the atmosphere have increased significantly since 1750. NOAA Climate.gov, Data: NCEI.

Heat gradually leaves the Earth's surface and is radiated back into space. Some heat is trapped by the gases in the atmosphere. These gases act like a giant greenhouse of warm air, keeping the Earth warm. If heat was not trapped, the temperature would drop to –100°C each night and rise to 80°C in the day. The gases that contribute to the greenhouse effect include carbon dioxide, water vapour, methane, nitrous oxide and ozone.

Since the Industrial Revolution of the eighteenth and nineteenth centuries, the level of greenhouse gases has been increasing, causing an enhanced greenhouse effect.

Increased levels of greenhouse gases

The concentration of carbon dioxide in the air has changed significantly, by approximately 34 per cent, since 1750. The bulk of that increase has happened since 1959. The concentration of methane in the atmosphere has also risen dramatically over the past century, more than doubling.

The main greenhouse gas is carbon dioxide. It is formed by the burning of fossil fuels, such as coal, petrol, oil and gas. We all use energy for heating, lighting, transport, industry and communications. Burning carbon-based fossil fuels releases energy (usually as heat) and produces carbon in the form of carbon dioxide and sometimes carbon monoxide or solid particulate carbon.

Forests consume carbon dioxide in the process of photosynthesis. Massive deforestation for farming and urban land has prevented carbon dioxide being removed from the air.

EXPERIMENT
6.5: What factors affect a greenhouse?
Go to page **203**.

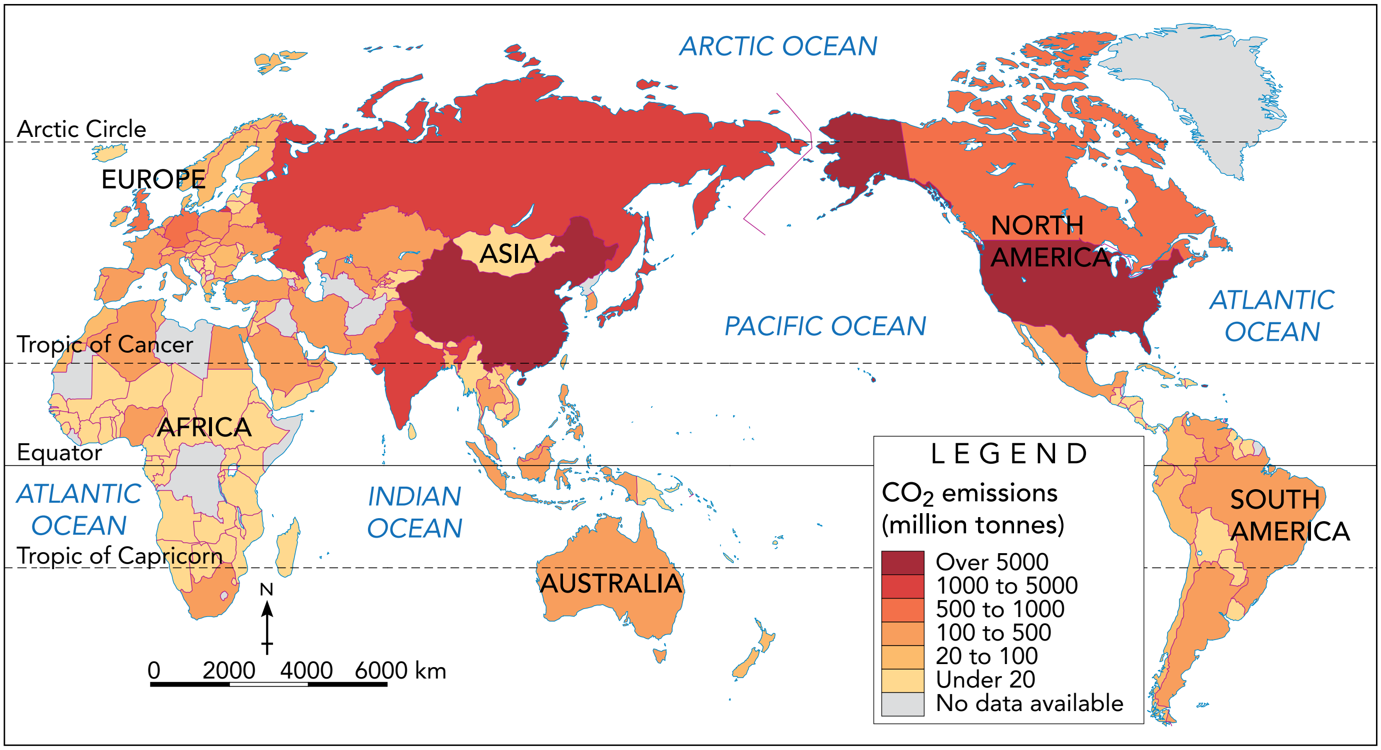


Figure 2 Global CO_2 emissions by area

This contributes to the increase in carbon dioxide levels. This increase in CO_2 production and decrease in absorption has resulted in an overall increase in the amount of carbon dioxide present in the atmosphere (Figure 1). Figure 2 shows which parts of the world emit the highest amounts of carbon dioxide.

Natural sources of methane gas in the Earth's atmosphere include the decay of organic materials in wetlands, termites, emissions from the oceans and the melting of methane hydrates, which are frozen forms of methane found in the ocean floor. Human activity also produces methane through energy production, increased emissions from livestock (e.g. cattle), landfill, biomass burning and waste treatment. The increase in these greenhouse gases has resulted in more heat being trapped in the atmosphere (Figure 4). Figure 5 shows how global temperatures have changed since 1900.

Melting sea ice

The ocean is very important in the regulation of global temperatures. It is a carbon sink, absorbing carbon, but it also absorbs up to 90 per cent of the solar radiation that hits the ocean.

As it warms, ocean water is less able to absorb solar radiation. The warmer water also causes sea ice to melt.

Sea ice is vast, shiny and bright white; it acts as a big mirror that reflects the Sun's radiation back out to space, once again keeping the Earth cooler (Figure 3). When this ice melts, more heat is absorbed by the water, increasing its temperature. The warmer water heats the atmosphere above it, driving a cycle that increases global temperature even further.

Figure 3 Arctic sea ice reflects heat from the Earth.

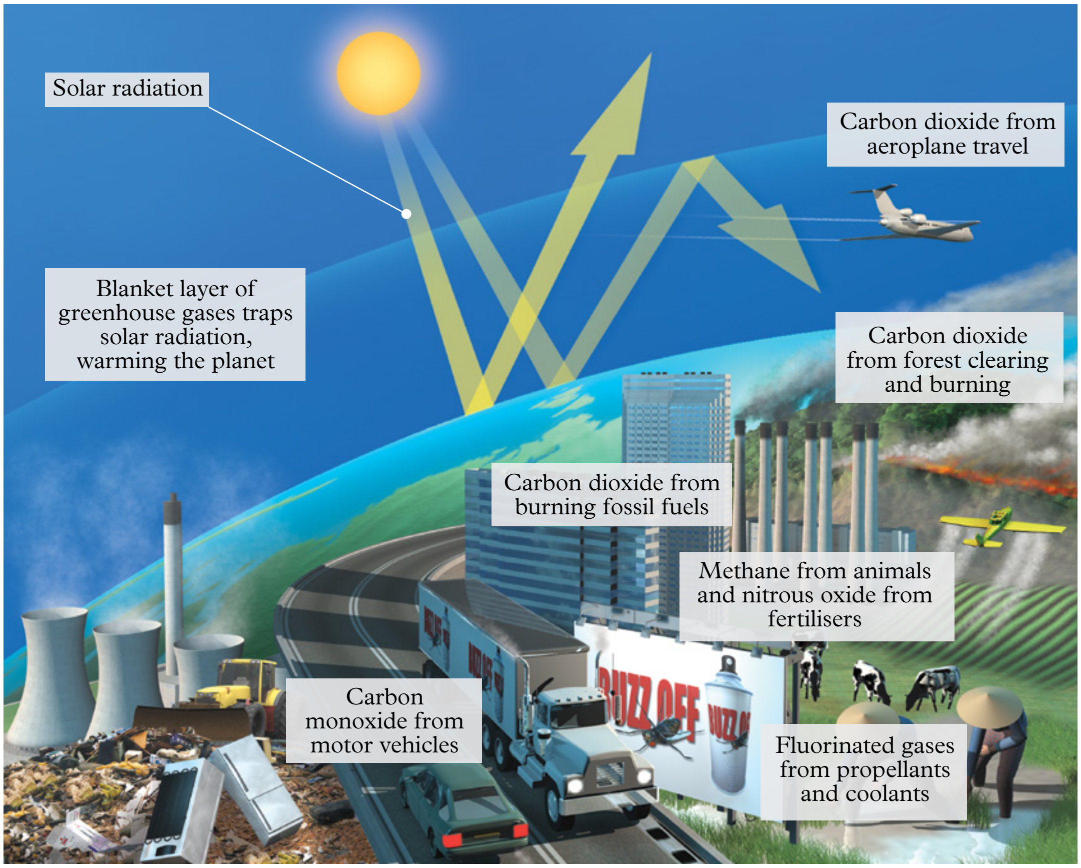


Figure 4 Factors contributing to human-induced climate change

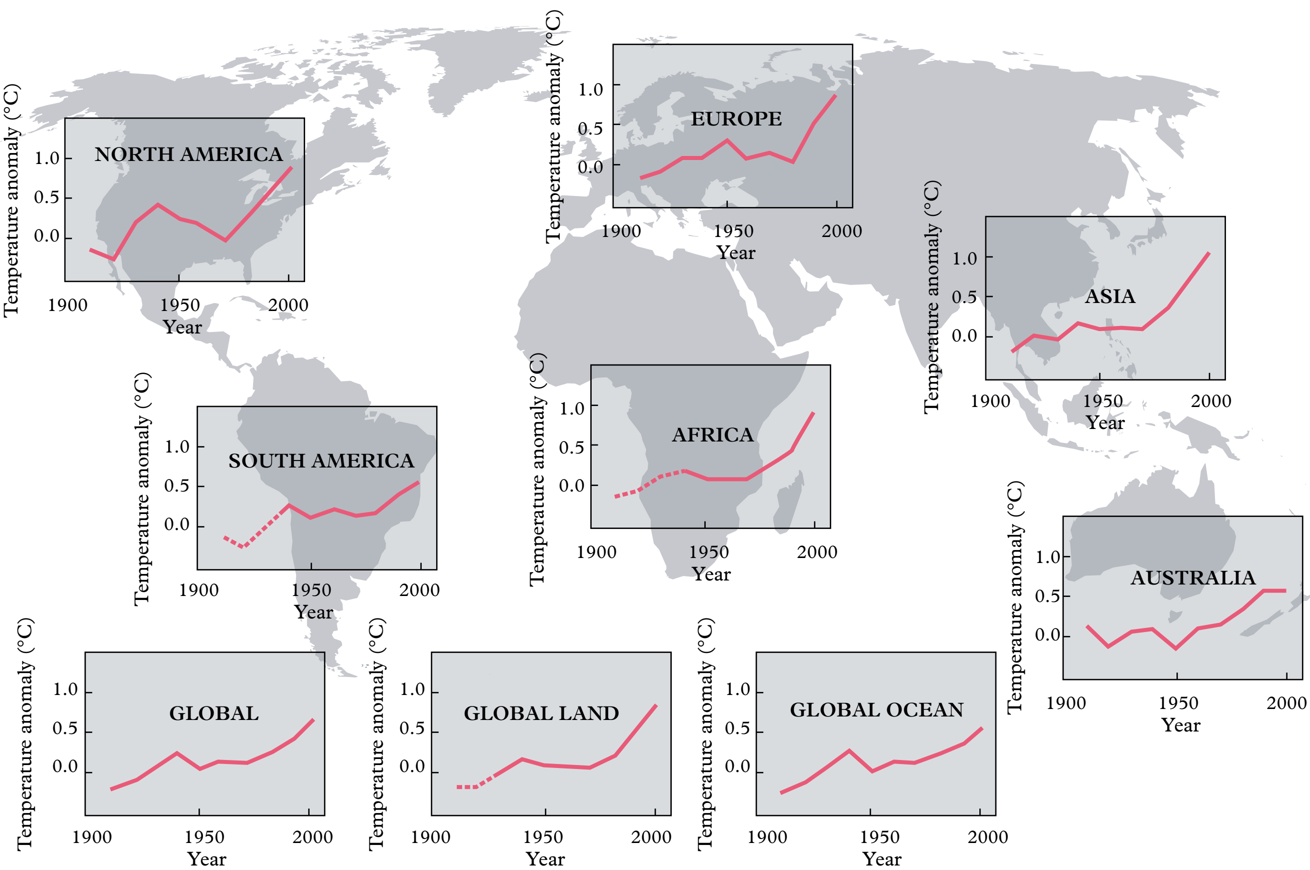


Figure 5 Global changes in temperature since 1900

Melting permafrost

Permafrost is permanently frozen ground that stores carbon from plant material frozen during the last Ice Age. Scientists have been measuring the temperature of the permafrost in Siberia for over 150 years and they have noticed an upwards trend. This means the ice is getting close to melting temperature (0°C) (Figure 6). Scientists believe that as much as two-thirds of the Earth's permafrost could disappear by 2200.

If the Earth's permafrost does melt, it will release thousands of years' worth of carbon into the atmosphere. This would equate to roughly as much as half of all fossil fuel emissions to date from when the world became industrialised.

Rising sea levels

The gravitational pull of the Moon (and Sun), together with the rotation of the Earth, mean there is a high tide approximately every 11 hours. Over many centuries, average water levels have varied. An Ice Age traps water in glaciers and sea ice, exposing land bridges for animals to migrate. These changes are very slow, taking thousands of years to affect sea levels. Over the last 100 years, there has been a dramatic change in sea levels as a result of enhanced greenhouse effect melting ice at the polar ice caps (Figure 7).

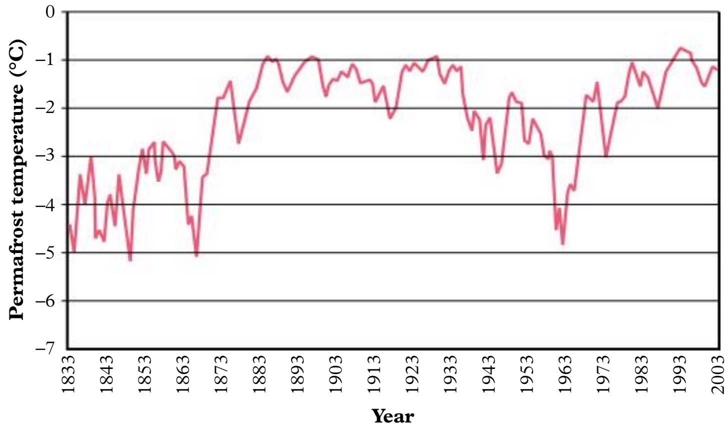


Figure 6 Historical measurements of Siberian permafrost temperatures at 5 m depth suggest that the permafrost is becoming warmer.

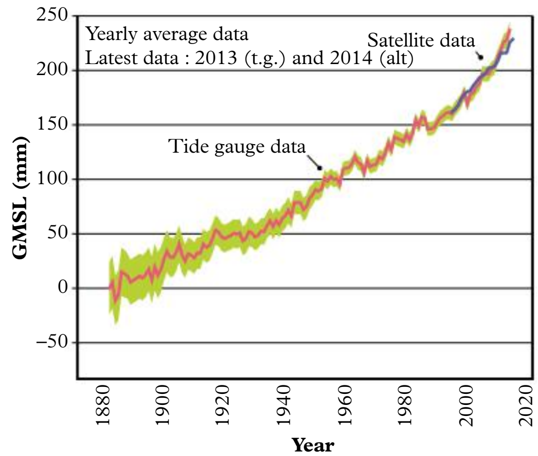


Figure 7 The CSIRO measured the global mean sea level (GMSL) from coastal tidal gauges and satellite data from 1880 to 2014. The overall trend indicates a consistent rise in sea levels.

permafrost
permanently frozen ground

6.5 Check your learning

Retrieve

1 **Identify** the two most significant carbon-containing greenhouse gases.

2 **Identify** how much the temperature on Earth has risen over the past century.

Comprehend

3 **Define** the term 'permafrost', and **explain** why it will add to greenhouse gas emissions if it melts.

4 **Explain** why climate scientists compare trends over many decades rather than data for one or two years.

5 **Explain** why the natural greenhouse effect is actually good for life on Earth.

Analyse

6 **Examine** the data shown in this topic. Use the data to support your opinion of the validity of global warming caused by the enhanced greenhouse effect.

7 Climate-change deniers suggest that the increase in sea levels is part of a normal cycle. **Investigate** and **compare** the timescale of previous global warming events to current climate change caused by the enhanced greenhouse effect.

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

//SCIENCE AS A HUMAN ENDEAVOUR//

6.6 Humans can reduce the effects of climate change

Learning intentions

By the end of this topic, you will be able to:
- describe the importance of the Kyoto Protocol
- explain how greenhouse gas emissions can be reduced by humans.

carbon tax
a tax levied on the carbon content of fuels used by businesses or homes

carbon trading scheme
the process of allocating a set limit of carbon credits to businesses, which can then trade the credits

The idea of climate change (previously called global warming) was first raised by the scientific community in 1977. As a result, scientists around the world began to coordinate their research in the World Climate Research Program. By 1983, the enhanced greenhouse effect was becoming a political issue. Currently, climate change is seen as a worldwide problem and this has influenced the focus of scientific research.

Kyoto Protocol

In 1997, an international treaty called the Kyoto Protocol was signed by many of the countries that are part of the United Nations. This document stated that global warming exists and that it is a result of carbon dioxide emissions arising from human activity.

Figure 1 The use of renewable energy, such as wind power, is one way to reduce carbon emissions.

The countries that signed the protocol agreed to start working to reduce carbon emissions by 2005. Australia ratified the agreement in 2007. This required the Australian Government to limit its average annual greenhouse gas emissions during 2008–2012 to 108 per cent of its emissions in 1990. In 2012, the protocol was amended to allow countries to extend the commitment to 2020, to allow time to create a new comprehensive climate treaty that would require all countries to reduce their emissions of greenhouse gases.

Paris Agreement

In 2015, a legally binding agreement was signed by all nations (rich, poor, developed and developing) to greatly reduce the amount of greenhouse gases that they produced. It has a system of monitoring and reporting the targets set by individual countries every five years. Australia has currently agreed to reduce its greenhouse gas emissions to 26–28 per cent below 2005 levels by 2030.

Reducing carbon emissions

Many governments are encouraging industries in their countries to reduce carbon emissions. Some governments are charging a fee for each tonne of carbon a business emits. This is often called a **carbon tax**. Other governments have instigated a **carbon trading scheme** where each business is allowed to release a predetermined amount of carbon emissions.

If a company needs to release more carbon dioxide or methane as part of their production process, then they must buy an allocation from another company. This also allows other industries to actively extract carbon dioxide from the atmosphere in order to sell 'carbon credits'. One carbon credit is often equivalent to one tonne of carbon dioxide.

CHALLENGE
6.6: Measuring carbon farming
Go to page **204**.

Geosequestration

The capture and storage of carbon dioxide underground is called geosequestration. This process, often employed by oil companies, involves capturing carbon dioxide from power station chimneys, separating it and compressing it into a liquid. The liquid is then pumped into depleted oil or gas wells and sealed with a solid plug of thick clay.

Carbon farming

Plants remove carbon dioxide from the air as part of photosynthesis. This carbon dioxide is converted into sugars and proteins that are then used by the plant to grow. Therefore, the greenhouse gas becomes part of the plant's structure. The carbon is considered to be locked in the plant for as long as it lives. For some trees this can be hundreds of years. Carbon farming is the process of growing plants that are not harvested for firewood, building or any other purpose (Figure 2).

Reducing methane production

Methane, another greenhouse gas, is often produced as a result of grass fermenting in a cow's stomach. Our increasing global population has meant a need for more food (including meat). This has resulted in more cattle being farmed and, therefore, more methane being released into the atmosphere.

Microbiologists at the University of Queensland are studying ways to modify the bacteria present in the stomachs of cows so that they do not produce as much methane. The model they use is the bacteria found in the foregut of kangaroos. This particular species of bacteria produces mainly acetic acid as a waste product. This acetic acid is then digested further by the kangaroo. It is hoped that the way these bacteria digest grasses can be mimicked by the bacteria in a cow, thereby reducing the emission of the greenhouse gas.

Small changes, big differences

There are many ways each person can reduce their climate impacts. These include:

- using public transport or car pooling
- switching off electrical appliances
- using renewable energy such as solar panels
- buying local produce, which prevents fossil fuels being used to transport food long distances
- reducing, reusing and recycling items to prevent them going into landfill and generating methane.

Our ability to make these changes is affected by social factors. A country with a low socioeconomic population will consider increasing wealth to be more important than future environmental concerns. The challenge is to support these countries in considering larger global issues as well as local issues.

Figure 2 Carbon farming removes carbon from the atmosphere and locks it away for hundreds of years.

6.6 Test your skills and capabilities

Scientific communication

Presenting data to an audience can take many forms. An increasingly common way to present important information is an infographic. Infographics are visual ways to present data so that the viewer can easily see the patterns. This can be through the use of graphs, pictures and important figures.

1 Select some of the key information you have learnt about climate change and plan an infographic for your peers.
   a **Decide** on the 1–2 key ideas that you want to present in your infographic. This should be reflected in the pictures and data that you use on the infographic.
   b **Identify** data (graphs or tables) in this chapter that support the key ideas.
   c **Identify** how you can present this data in a simple and effective manner. Use pictures of different sizes to represent different values (Figure 3).
   d Write the key ideas in a short phrase or sentence so that they are obvious to the viewer.

Figure 3 Data such as increasing storm strength or biodiversity can be represented in different ways.

CHAPTER 6 REVIEW

THE CARBON CYCLE

Retrieve

1 **Identify** the best definition for the lithosphere.
   A the outermost rocky layer of the Earth including the mantle and crust
   B the layer of gases that surrounds Earth and other planets
   C the intersection between the atmosphere, hydrosphere and biosphere
   D the collection of all the Earth's water

2 Which of the following would not reduce carbon emissions?
   A charging a carbon tax
   B using public transport
   C using solar energy
   D using fire instead of electricity

3 **Identify** the best definition for the cryosphere.
   A the layer of gases we commonly call air
   B all the Earth's water
   C frozen water in the hydrosphere
   D the rocky outermost layer of Earth

4 **Identify** which of the following statements are true and which are false.
   a Carbon farming is the process of releasing carbon into the atmosphere.
   b The Paris Agreement is a legally binding agreement through which European nations agreed to greatly reduce the amount of greenhouse gases they produced.
   c Geosequestration is the capture and storage of carbon underground.
   d Climate change is caused by melting permafrost.

5 **Identify** the layer of the Earth where the tectonic plates are found.

6 The biosphere includes parts of the atmosphere, lithosphere and hydrosphere. **Identify** two elements of the biosphere you may find in each of these three spheres.

Comprehend

7 **Identify** three gases that are found in our atmosphere and **explain** why they are important to life on Earth.

8 **Describe** one way carbon can move from the atmosphere to the biosphere.

9 **Explain** how the lithosphere contributes heat to the atmosphere.

10 **Describe** two ways carbon can move from the biosphere to the atmosphere.

11 **Describe** one way that increased industrialisation, particularly since the nineteenth century, has affected the carbon cycle.

12 **Describe** how agriculture has increased the amount of greenhouse gases in the atmosphere.

13 **Describe** two predicted outcomes of rapid climate change.

14 The hydrosphere is often considered a carbon sink.
   a **Define** the phrase 'carbon sink'.
   b **Identify** the chemical reaction that occurs as a result of the ocean acting as a carbon sink.
   c **Describe** the impact on marine life that occurs as a result of the ocean acting as a carbon sink.

15 **Explain** the process of combustion and how it contributes to the enhanced greenhouse effect.

16 The glaciers on Mount Kilimanjaro in Tanzania are disappearing eight times faster than 20 years ago due to climate change. **Explain** how cloud cover can affect the atmospheric temperature and the melting of glaciers.

Figure 1 Notice the snow cap on Mount Kilimanjaro.

17 **Describe** two ways humans are trying to reduce rapid climate change due to the enhanced greenhouse effect.

18 **Describe** the impact of bushfires on the carbon cycling through the Earth's spheres.

19 The human population was fairly stable until about 1 CE. Then it started to grow, and its growth accelerated until it almost reached an exponential rate. In the past century, the human population has almost quadrupled. **Describe** two impacts of the population increase on world ecosystems.

Analyse

20 **Contrast** the greenhouse effect and the enhanced greenhouse effect.

21 **Contrast** the rate the climate changed millions of years ago to the way the enhanced greenhouse effect is causing climate change.

Apply

22 **Evaluate** the effects of melting permafrost on climate change (by defining 'permafrost', describing the effects of melting permafrost on Earth's spheres, and deciding whether these effects will contribute to climate change).

Figure 2 Melting permafrost can impact Earth's spheres.

23 The northern bettong is a very small, endangered nocturnal marsupial (Figure 3). It is an omnivore that eats small invertebrates, herbs, grasses and a species of fungus that makes up approximately 45 per cent of its diet. Northern bettongs were once widely distributed throughout Queensland. However, there are now only three populations left along the western edges of the wet tropics of north Queensland.

Investigate the northern bettong on the internet. **Describe** the human activities that are contributing to the northern bettong being listed as endangered.

Figure 3 The northern bettong is an endangered species.

Social and ethical thinking

24 Over 80 per cent of the Earth's energy resources are non-renewable and declining. In the twentieth century, most energy use was concentrated in a few nations that make up only a small proportion of the Earth's population. The seven largest economies at the beginning of the twenty-first century (with 10 per cent of the global population) used approximately 45 per cent of the total primary energy supply. Yet, approximately 2 billion people on Earth do not have access to electricity. In a group, **discuss** the ethical fairness of this distribution.

Critical and creative thinking

25 **Create** a diagram that identifies the way carbon moves between Earth's spheres.

26 **Construct** a chart or table that describes environmental carbon sinks and carbon producers.

27 **Create** a mind map showing the potential connections and dependencies between the four spheres of the Earth and their components. **Identify** as many links as possible.

28 Combustion for electrical energy is one of the most common ways humans contribute carbon to the atmosphere. Imagine you had to reduce your energy impact on the environment. Look at all the appliances and gadgets you use in your home. **Identify** one of these that you could absolutely not bear to give up. **Create** an A4 page outlining why this one item is 'essential' to you and then make a list of appliances and gadgets that you could live without.

29 Manufacturers of solar panels claim that solar power is better for the environment. **Investigate** solar panels and **evaluate** the manufacturers' claim (by describing the materials used in the manufacture of solar panels, the energy needed to produce them, how long a panel will last and what happens to a solar panel when it reaches the end of its life. Compare these factors to the benefit of the solar energy generate and decide if the manufacturers claim is valid.)

30 The Earth's climate and weather are the result of global interactions between systems and cycles. **Evaluate** how this supports the argument that logging in any country affects everyone else on the planet (by describing how trees contribute to the atmosphere, hydrosphere and biosphere, describing how the sphere in one country affects other countries, and describing how the spheres affect weather and climate).

Research

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

» Responding to global warming

The Kyoto Protocol is an international treaty which states that global warming exists and is a result of carbon emissions arising from human activity. Australia didn't ratify the agreement until 2007.

- » Identify the measures that Australia agreed to commit to.
- » Describe the strategies that Australia has used to meet its commitments.
- » Evaluate how successfully Australia has met those commitments.

Figure 4 The Kyoto Protocol acknowledged the existence of global warming and the fact that it is a result of human activity.

» Landcare Australia

Landcare Australia is an organisation involved in developing and providing a sustainable approach to integrated land management and building resilience in food and farming systems.

- » Investigate the nearest Landcare group to your area.
- » Describe the work that they do.
- » Explain how this could improve soil quality and increase carbon sequestration in soils.

Landcare Australia

Figure 5 Landcare Australia

» Climate change: Global warming or ice age?

Like the Earth, the Sun demonstrates cycles of behaviour. One such pattern that has been identified is a period during which sunspots are absent. The lack of sunspots could result in a global temperature decrease for the Earth.

- » Investigate sunspots and the solar cycle.
- » Describe what a sunspot is.
- » Explain what the solar cycle is.
- » Contrast a solar maximum and a solar minimum.
- » Investigate the potential impact of the solar cycle on the Earth's climate.

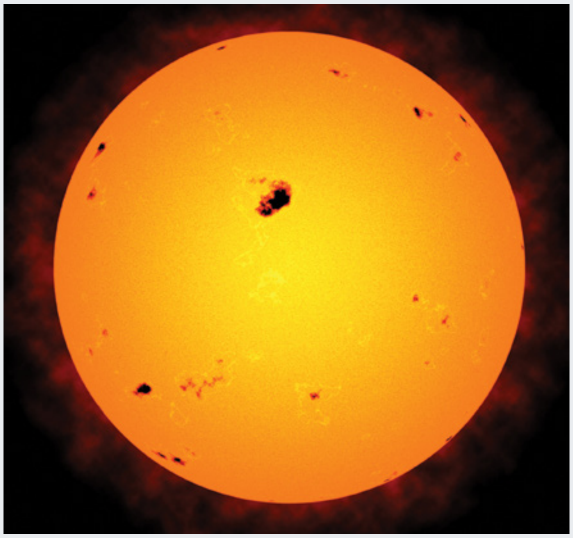


Figure 6 Scientists can use the presence of sunspots to track the solar cycle.

Chapter checklist

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

	I can do this.	I cannot do this yet.
• Identify the differences between the lithosphere, atmosphere, hydrosphere and biosphere. • Explain how the spheres interact with one another.	☐	☐ Go back to Topic 6.1 'The Earth's spheres are balanced'. Page 112
• Explain the main processes involved in the carbon cycle. • Explain the processes involved in photosynthesis. • Identify the reactants and products of photosynthesis and cellular respiration, and describe why they are not reversible versions of each other.	☐	☐ Go back to Topic 6.2 'Carbon cycles through Earth's spheres'. Page 116
• Explain how matter moves through the carbon cycle and identify the key participants. • Apply the carbon cycle to explain a carbon sink. • Identify and describe the impact that humans have on the carbon cycle.	☐	☐ Go back to Topic 6.3 'Human activity affects the carbon cycle'. Page 120
• Contrast hazard reduction burning and cultural burning. • Describe how First Nations knowledge and the practice of cultural burning can reduce carbon emissions.	☐	☐ Go back to Topic 6.4 'Traditional knowledge reduces carbon emissions'. Page 122
• Explain the trend in increased temperature over time. • Explain why greenhouse gas concentrations in the atmosphere are rising.	☐	☐ Go back to Topic 6.5 'Evidence supports the enhanced greenhouse effect'. Page 124
• Describe the importance of the Kyoto Protocol. • Explain how greenhouse gas emissions can be reduced by humans.	☐	☐ Go back to Topic 6.6 'Science as a human endeavour: Humans can reduce the effects of climate change'. Page 128

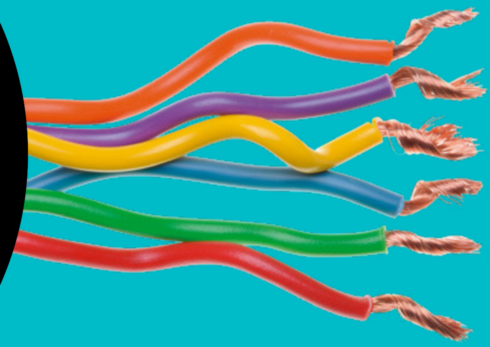
Check your Student obook pro for these digital resources and more:

Quizlet
Play a Quizlet game to test your knowledge.

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

CHAPTER

7



PARTICLES AND WAVES

7.1

Heat can be transferred by convection and conduction

> Explain how heat energy is transferred by conduction and convection in terms of the motion of particles.

7.2

Vibrating particles pass on sound

> Describe the motion of molecules in a longitudinal wave.

7.3

Sound can travel at different speeds

> Explain why sound does not travel through space.

> Describe how the transmission of sound can be affected by the density of the medium it travels through.

7.4

Electricity is the presence and flow of charged particles

> Describe the difference between static electricity and electric current.

> Identify the key components of an electric circuit.

7.5

Current can flow through series and parallel circuits

> Describe the differences in arrangement of series and parallel circuits.
> Measure current using an ammeter.

7.6

Voltage is the difference in energy between two parts of a circuit

> Describe how voltage is shared in series circuits and in parallel circuits.
> Measure voltage using a voltmeter.

7.7

Visible light is a small part of the electromagnetic spectrum

> List the classes of electromagnetic radiation and their average wavelengths.
> Explain how light behaves as a wave and how it behaves as a particle.

7.8

Light reflects off a mirror

> Describe the characteristics of a virtual image.
> Demonstrate appropriate use of a Hodson light box.

7.9

Light refracts when moving in and out of substances

> Describe the refraction of light through a convex and concave lens.
> Explain the difference between focus and virtual focus.

7.10

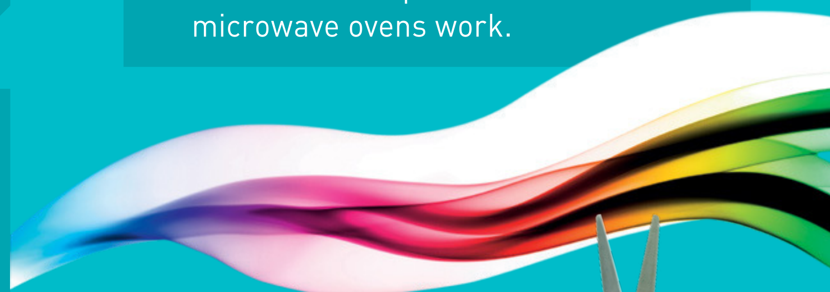
Different wavelengths of light are different colours

> Describe how we see the colour of opaque and transparent objects.
> Explain how the primary colours of light can generate secondary colours of light.

7.11

The electromagnetic spectrum has many uses

> Define critical angle, total internal reflection and optic fibre.
> Describe how optic fibres and microwave ovens work.



What if?

String phones

What you need:

2 foam cups, 3 m of string, scissors

What to do:

1 Place a small hole in the bottom of each cup.
2 Poke each end of the string through the bottom of a cup and tie it off. The two cups should now be connected.
3 Pull the string taut between two people.
4 One person should speak quietly into the cup at one end while the second person listens in the other cup.

What if?

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

7.1 Heat can be transferred by convection and conduction

Learning intentions

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

- explain how heat energy is transferred by conduction and convection in terms of the motion of particles.

Key ideas

- The energy from heat moves spontaneously from a hot material to a cool material.
- Conduction occurs when the kinetic energy of particles is transferred.
- Convection occurs when a particle with high kinetic energy moves to another space.

conduction
the transfer of thermal energy from hot objects to cooler objects by direct contact with no movement of material

thermal conductor
a material that allows thermal energy to flow through

thermal insulator
a material that prevents or slows down the transfer of thermal energy

Modelling energy transfer

In Year 8 you discovered how energy can be transferred from one substance or medium to another. The way the energy is transferred can vary depending on the type of energy that is being transferred. This can be modelled using wave or particle models to explain the movement of the energy. Throughout this chapter we will look at the different ways to model thermal (heat) energy, sound energy, electrical energy and light energy.

Modelling thermal energy

The particle model suggests that all things are made up of particles of atoms or molecules that have kinetic (movement) energy. Solid objects have vibrating particles that are bonded closely together. If thermal energy is added to a solid object, the particles start vibrating faster until they can move around one another. This increase of energy and movement turns the solid into a liquid. If more energy is added to the liquid, particles will start moving faster until they are able to break free and move freely as a gas (Figure 1).

When modelling thermal energy, it is important to consider the movement of the heat. Cold objects have less thermal energy and hot objects have more thermal energy.

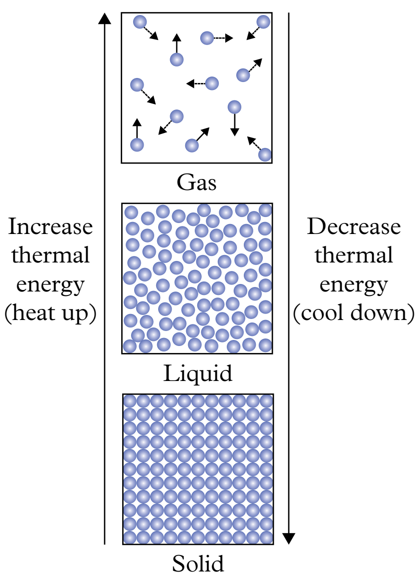


Figure 1 Increasing or decreasing thermal energy can change the movement of particles and the state of an object.

Heating by conduction

Heating an object by **conduction** involves the transfer of thermal energy between two objects that are in contact with each other. The energy is transferred from an object with high thermal energy to an object with low thermal energy (from hot objects to cooler objects).

This continues until the two objects are the same temperature (equal amounts of thermal energy).

Consider what happens when we heat a saucepan of water on a gas burner.

1 When the gas burns, thermal energy is released.
2 The hot molecules in the gas flame move quickly and occasionally bump into atoms of the relatively cold metal of the saucepan.
3 Kinetic energy passes to the slowly vibrating atoms in the saucepan so that they vibrate faster.
4 The quickly vibrating atoms in the saucepan bump into other nearby metal atoms, transferring thermal kinetic energy to them. This heats the saucepan.
5 When the saucepan heats up, the thermal kinetic energy is transferred to the water inside it.

Although the thermal energy moves through the metal of the saucepan and into the water, the atoms in the metal do not change their positions – metal atoms do not move into the water.

Conductors and insulators

A **thermal conductor** is any material that allows thermal energy to flow easily through it. All metals are conductors of thermal energy, although some are better conductors than others. **Thermal insulators** are materials that slow down the transfer of thermal energy because the molecules don't allow the thermal kinetic energy to flow very easily. Insulators such as socks, jumpers and blankets keep us warm in cold weather. They make it difficult for our 'body heat' to escape, insulating us against the cold. Insulation in the roof and walls of a house prevents heat gain and loss during summer and winter. Insulation can hold thermal energy in or keep it out.

EXPERIMENT **7.1A:** Investigating heating by convection
Go to page **205**.

EXPERIMENT **7.1B:** Testing insulating materials
Go to page **206**.

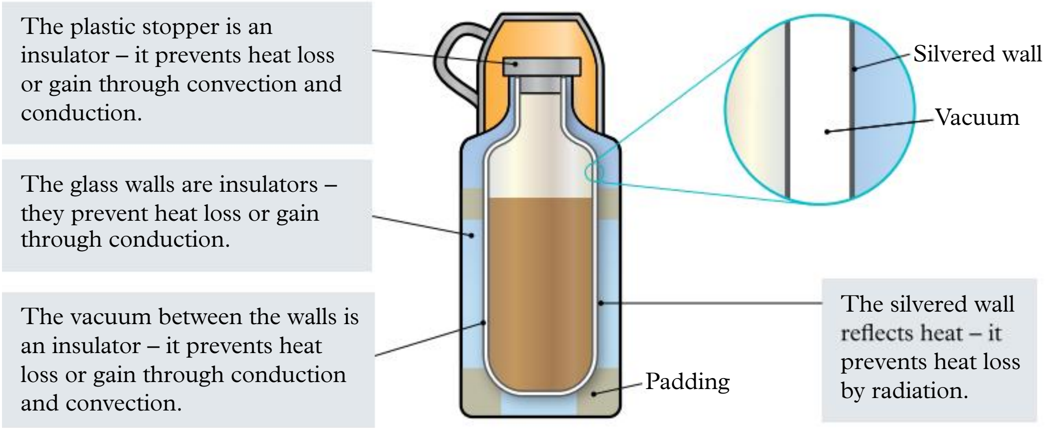


Figure 2 Vacuum flasks are designed to keep hot substances hot and cold substances cold. To do this they must prevent the contents from losing or gaining heat – conduction and convection must be minimised. Careful choice of materials and clever design make this possible.

You can test the thermal conductivity of the different materials around you. If you put your hand on a metal object, it will feel cold to touch. This is because the metal conducts heat away from your hand, making it feel cold. If you touch a wood object, it will feel warmer than the metal object. In reality, both objects will be exactly the same temperature, but the wood acts like a thermal insulator, preventing the thermal energy from being conducted away from your hand. Because your hand is not losing heat, it will feel warm.

Heating by convection

The particles in liquid and gas materials are able to move more freely than in solid objects. In these materials, thermal energy moves by **convection**. As the particles gain thermal kinetic energy, they are able to move away from the heat source. Tiny currents, called **convection currents**, carry the particles and their thermal energy across the liquid or gas until the heat is evenly spread.

When we heat a saucepan of water on a gas flame, the following occur.

1. Thermal energy transfers by conduction from the hot saucepan to the water molecules that are touching the metal.
2. The water molecules in contact with the metal gain kinetic energy and move faster than the molecules in the water above. Because they are moving faster, they take up more space. They are less dense.
3. As a result, the heated (less dense) water molecules near the bottom of the saucepan begin to rise, leaving room for the cooler (more dense) water molecules to take their place (Figure 3).
4. The heated water molecules take thermal energy with them as they move.

We heat liquids from below because most of the energy transfer in liquids (and gases) takes place by convection. This process happens in the air. The Sun heats the ground and the warmed ground then heats the air next to it by conduction. The warmed air, being less dense than the cooler air above, rises, taking the thermal energy with it. This distributes the energy through a much deeper layer of air than could occur just by conduction from the ground. This process of convection in the air is what drives the weather on Earth.

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

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

Figure 3 Convection currents are created in a saucepan of water when it is heated. The heated water molecules (shown in red) rise while the cooler ones (shown in blue) sink.

7.1 Check your learning

Retrieve

1. **Identify** two examples of situations where thermal energy is transferred by:
   a conduction **b** convection.

Comprehend

2. **Identify** one example of where good thermal insulators and conductors are needed in everyday life. **Describe** the materials that are used in each situation.
3. Some modern saucepans have a copper bottom, steel sides, a plastic handle and a glass lid. **Explain** why each of these materials is used for particular parts of a saucepan.
4. Think of a situation where you can see expansion due to heating of a solid, liquid or gas. **Explain** what the molecules or atoms are doing to cause the expansion.

Analyse

5. **Consider** why scientists are happy to refer to thermal energy transfer as heating, even though in every case something is being cooled.

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

7.2 Vibrating particles pass on sound

Learning intentions

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

- describe the motion of molecules in a longitudinal wave.

Key ideas

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

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

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

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

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

Modelling sound waves

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

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

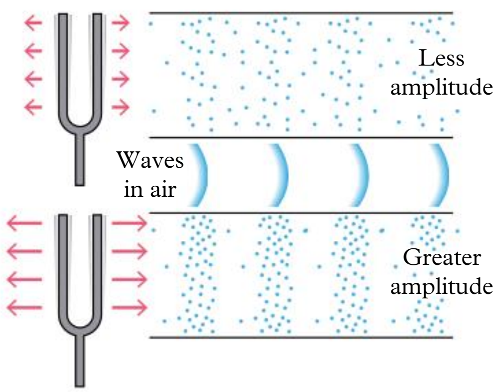


Figure 1 Red arrows indicate how far a particle in a sound wave moves.

The region with the particles forced close together is called a **compression**, and the less dense region where the air particles are further apart is called a **rarefaction**. Sound waves travel as a **longitudinal wave** because the air particles move back and forth parallel to the wave as the vibration passes through the air. The distance a particle of air moves is called the **amplitude** of the wave (Figure 1). Sound waves with a large amplitude mean the air particles move with greater kinetic energy. This makes the sound feel louder to our ears. An example of this is when musicians use amplifiers to increase the loudness of their music. Amplifiers increase the distance air particles move during compression and rarefaction.

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

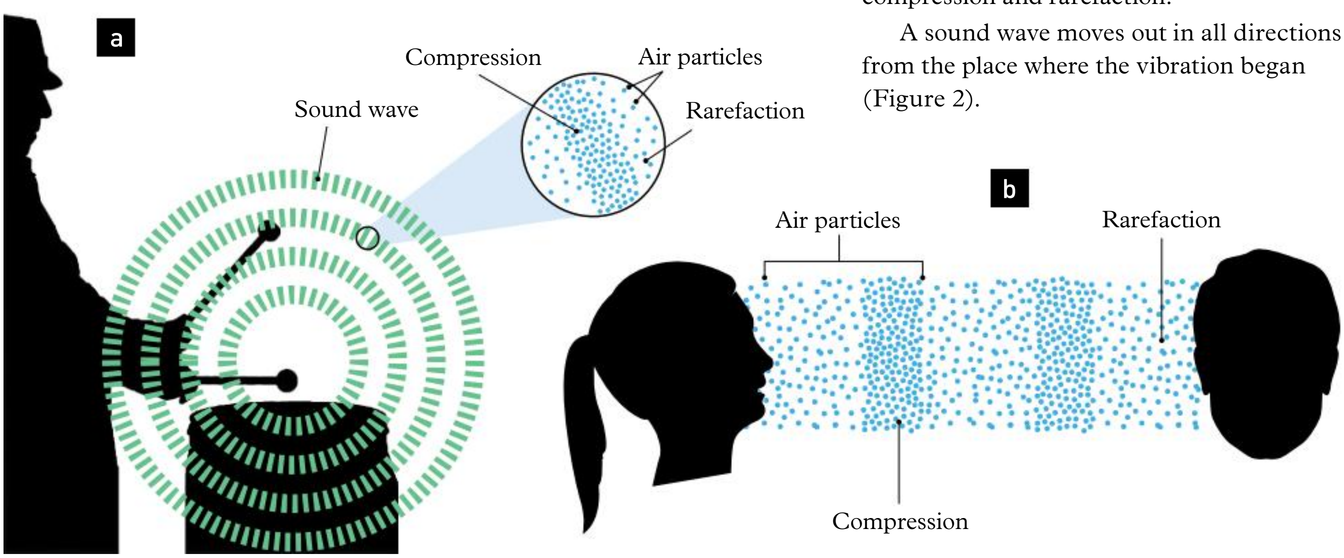


Figure 2 a When a drummer hits a drum skin and **b** when a person speaks, a sound wave is produced.

CHALLENGE

7.2: Modelling sound waves
Go to page 207.

Describing sound

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

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

When the waves travel close together, they are considered more frequent. The number of waves that pass a point each second is called the **frequency** of the wave.

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

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

hertz
the unit used to measure frequency

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

wavelength
the distance between two crests or troughs of a wave

Video 7.2
Vibrating particles pass on sound

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

7.2 Check your learning

Retrieve

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

Comprehend

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

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

Analyse

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

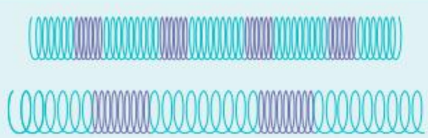


Figure 4 Springs

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

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

Apply

7 **Investigate** how the speed of sound in air changes in different temperatures (HINT: Hot air has faster moving particles).

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

7.3 Sound can travel at different speeds

Learning intentions

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

- explain why sound does not travel through space
- describe how the transmission of sound can be affected by the density of the medium it travels through.

Key ideas

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

Sounds of silence

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

A famous sci-fi movie was advertised with the tagline 'In space, no one can hear you scream'. The moviemakers were right. In outer space, you could play your drum kit without anyone hearing a sound – but you wouldn't hear it either. You could even see an explosion without hearing a thing. This is because sound needs something to travel through; it needs a substance (or medium) that contains particles that can be compressed to create the sound waves. The medium could be a solid, a liquid or a gas. In space, the particles are too far apart to push against each other (Figure 1).

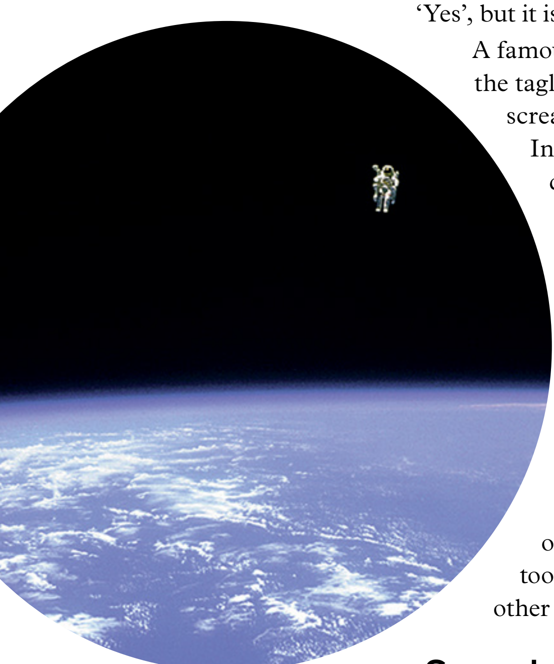


Figure 1 In outer space, there are so few particles of gas, and they are so far apart, that they cannot be compressed. As a result, outer space is silent.

Speed of sound

The speed of sound is affected by the closeness of the particles in a material, and how far they can move. For example, the particles in water are much closer together than in air. This means the water particles can move and compress more easily than air particles. Sound such as the song of a whale will travel more easily through water than air (Figure 2). The particles in a solid are packed even closer together. Therefore, sound will travel even faster in most solids (Table 1).

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

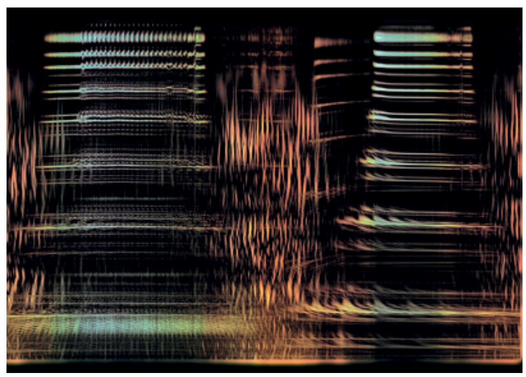


Figure 2 Sound travels five times faster in water than in air. Blue whales sing to each other in a series of moans and pulses (shown) that can travel thousands of kilometres underwater.

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

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

Sonar

Since the First World War, reflected waves have been used to detect enemy submarines under water.

CHALLENGE

7.3A: The speed of sound
Go to page **208**.

CHALLENGE

7.3B: Racing dominoes
Go to page **209**.

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

Sonar is widely used today and can help to map the ocean floor, check the depth of water and locate schools of fish (Figures 3 and 4).

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

sonar
the detection of the location of objects through the use of soundwaves

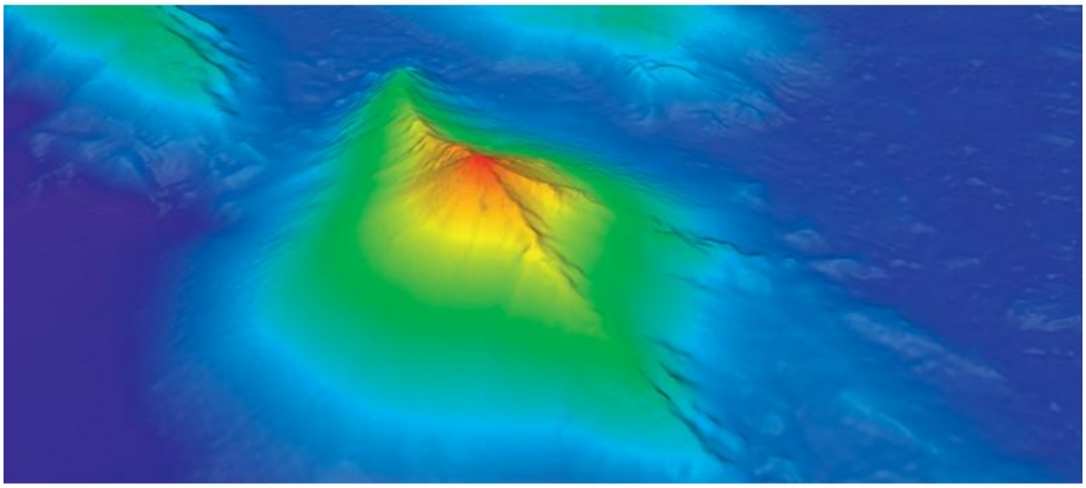


Figure 4 Sonar is used to map volcanoes on the ocean floor.

7.3 Check your learning

Retrieve

1 **Identify** which of the following materials will allow sound to travel the fastest.

a water
b lead
c air
d glass

Comprehend

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

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

Analyse

4 **Compare** sound moving through gases and solids.

Apply

5 Echoes occur when sound bounces off smooth surfaces. **Identify** which of the following is most likely to produce a loud echo. **Justify** your answer (by describing how sound moves in each case and deciding which will produce the loudest echo).

a talking in a furnished, carpeted room
b singing in a tiled shower
c yelling across an open field

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

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

7.4 Electricity is the presence and flow of charged particles

Learning intentions

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

- describe the difference between static electricity and electric current
- identify the key components of an electric circuit.

Key ideas

- Electrostatic charges occur when electrical charges are unable to move.
- A closed circuit occurs when the positive and negative charges can be separated and reunited.
- An electrical conductor allows the charges to flow easily.
- An electrical insulator restricts the movement of the charges.

electrostatic charge
an electrical charge that is trapped in an object such as a balloon

van de Graaff generator
a machine that produces an electrostatic charge

electrical energy
the energy that results in the movement of electrons through a conductor towards a positive charge

'Electricity' is a general term related to the presence and flow of charged particles. An electric charge can be either positive or negative. It is produced by subatomic particles (parts of atoms) such as electrons, which carry a negative charge, or protons, which carry a positive charge.

Electrostatic charge

Objects are normally uncharged – their atoms usually have equal numbers of positive protons and negative electrons. But when two objects are rubbed together, some of the electrons may be transferred from one object to the other. This causes the object with fewer electrons to become positively charged and the one with extra electrons to become negatively charged. You can see examples of this with other examples of friction – for example, if you rub a balloon against a woollen jumper, take off synthetic clothing or walk across synthetic carpet. In all these cases, the positive or negative electric charge stays on the charged object without moving. This is called an **electrostatic charge**. When the charges on an object are the same (both positive or both negative), then they are described as 'like charges'. If the charges are different (one positive and one negative), then they are described as 'unlike charges'.

Important rules to learn about electrostatics:

> Like charges repel.
> Unlike charges attract.
> Charged objects attract neutral objects.

When charged objects are close to each other, the small negative electrons are attracted to the positively charged object (unlike objects attract). If these two objects are brought close enough, the electrons will try to jump across

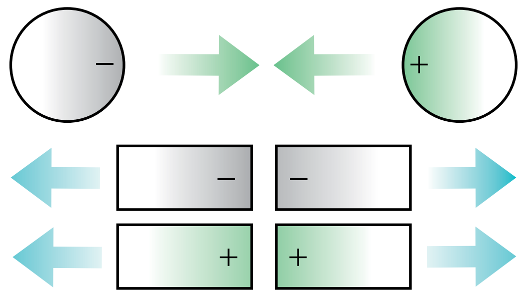


Figure 1 Like charges repel, unlike charges attract.

the gap as a spark. This is what happens when the air particles in a cloud rub against each other and become charged. If the charges build up enough, a large spark (lightning) will move between the charges in the clouds or towards the neutral ground (charged particles and neutral objects are attracted to each other).

The **van de Graaff generator** is a machine that produces an electrostatic charge by rubbing a belt (Figure 2). It is used to accelerate particles in X-ray machines, food sterilisers and process machines, and in nuclear physics demonstrations.

Electrical energy and circuits

When electric charges become separated, they have **electrical energy**. This means they are in a state of excitement and the positive and negative charges try to get back together again. If a closed circuit is provided, the electrons will move along the wire to the positive charges and, as they do so, the electrical energy may transform into some other forms of energy, such as light or thermal energy.

However, it is difficult to continually rub things together to separate charges and give them electrical energy.

Figure 2 When the girl places her hands on the van de Graaff generator, charge passes from the dome through to her hair, where like charges repel.

CHALLENGE
7.4A: Demonstrating electrostatics
Go to page **210**.

CHALLENGE
7.4B: Separating charges with a van de Graaff generator
Go to page **211**.

A **dry cell** (for example, a torch battery) or a **wet cell** (for example, a car battery) uses a chemical reaction to continually separate charges and produce current electricity through wires.

A closed conducting pathway is called an **electric circuit**. As electrically charged particles move around an electric circuit, they carry energy from the energy source (such as a battery) to the device that transforms the energy (such as a light globe, motor or heater). An example of the movement of electrical energy in a simple circuit is shown in Figure 3.

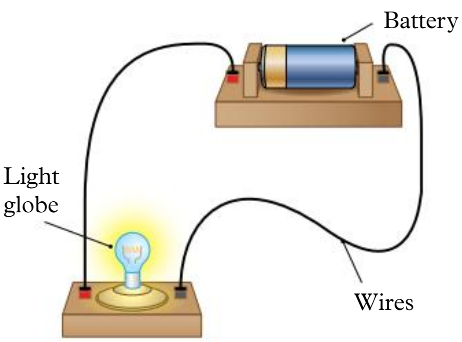


Figure 3 A simple circuit: electric charges move from the battery through the wires to the light globe.

Measuring electric current

Electric current, or the flow of charge, is measured by counting the number of electrons that go past a point in the circuit in 1 second. The unit of measurement for current is amperes (symbol A). An ampere is a large unit of current, so smaller units, such as the milliampere (1000 mA = 1 A), are often used. Traditionally an ammeter (Figure 4a) was used to measure the current passing a particular point in an electric circuit. The ammeter must be connected into the circuit so that the current flows through it. More recently, a multimeter (Figure 4b) is used to measure many different aspects of a circuit, including the current.

a **b**

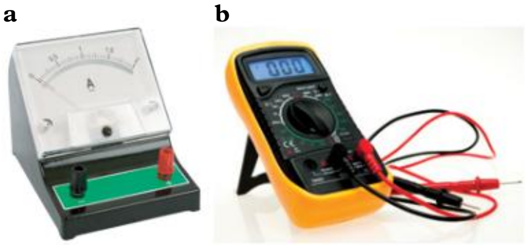


Figure 4 a An ammeter or **b** a multimeter is used to measure electric current.

Electrical conductors and insulators

An **electrical conductor** is a material through which charged particles are able to move. An **electrical insulator** is a material that does not allow the current of charged particles to move. Most wires are made of copper, a metal, with a plastic coating around the outside. Copper is an electrical conductor – electrons are able to move through it easily. However, plastic is an electrical insulator. The wires are coated in plastic to prevent the current being 'lost' to the surroundings as it passes through the wires.

Some substances are better **insulators** or better conductors than others. It depends on how easily they allow electrons to move through them – that is, they offer less or more resistance to the movement of charges. Air is a good resistor, because it is difficult for charged particles to move freely.

Some substances, such as germanium and silicon, are insulators in their pure form but become conductors if they are combined with a small amount of another substance. These materials are called **semiconductors**.

Within a single silicon chip, very thin layers of silicon can be combined with other substances to make that layer a conductor. Complex microcircuits used in computing are made in this way.

dry cell
an object, such as a torch battery, that uses a chemical reaction to produce electrical energy

wet cell
an object, such as a car battery, that uses a chemical reaction to produce electrical energy

electric circuit
a closed pathway that conducts electrons in the form of electrical energy

electrical conductor
a material through which charged particles are able to move

electrical insulator
a material that does not allow the movement of charged particles

insulator
a substance that prevents the movement of thermal or electrical energy

semiconductor
a material that conducts electrical energy in one form and insulates against electrical energy in another form

7.4 Check your learning

Retrieve

1 **Identify** the charge on the following particles.
   a protons
   b electrons

2 **Define** the term 'current'.

Comprehend

3 **Describe** how objects can become electrostatically charged.

4 **Explain** the purpose of a battery in a circuit.

5 **Describe** an electric circuit.

6 **Describe** how a semiconductor works.

Analyse

7 **Compare** a conductor and an insulator.

Apply

8 If living organisms are good conductors and air is a good resistor, **discuss** why it would be dangerous to stand in open land during a lightning storm.

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

7.5 Current can flow through series and parallel circuits

Learning intentions

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

- describe the differences in arrangement of series and parallel circuits
- measure current using an ammeter.

Key ideas

- In a series circuit, the loads are connected one after the other, and the current is the same throughout the circuit.
- In a parallel circuit, the loads are parallel to one another, and the current is shared between them.
- A short circuit occurs when the electrical energy can move through an easier path with less resistance.

parallel
the positioning of loads (e.g. lights) in an electric circuit so that they are connected to the battery separately; they are in parallel to one another

series
the positioning of loads (e.g. lights) side by side in an electric circuit so that the electrical energy passes through one load at a time

Types of circuit

When two or more globes are connected in a circuit, two different types of connection are possible. In a series circuit, the globes are connected one after the other so that the current goes through one globe and then through the second (Figure 1a). In a parallel circuit, the circuit has two or more branches and the current splits between the branches (Figure 1b) and comes back together afterwards.

Comparing series and parallel circuits

If two globes are connected in a circuit in series, then all the current (the electrons) passes through both globes (Figure 1a). This means the current is always the same at all points in a series circuit.

However, if two globes are connected in parallel, the current splits (Figure 1b). This means when the electrons reach the point where the wire splits, the electrons will travel along one path or the other. Part of the current passes through each globe, and then joins together again after passing through the globes. This means the currents going through each globe must be added together to determine the total amount of current coming from the battery.

In a series circuit, a break at any point in the circuit (for example, from a switch) affects all the globes in the circuit. In a parallel circuit, a break in one of the branches of the circuit affects only the current (and globe) in that branch.

In a household, lights and appliances are connected in parallel so that:

> some appliances can be on while others are off (achieved by inserting switches)
> if one appliance fails, the others will still work (Figure 2).

Figure 2 Traditionally, party lights were a series circuit. This meant that when one light broke, all the lights went out. Now, most modern party lights are arranged in a parallel circuit.

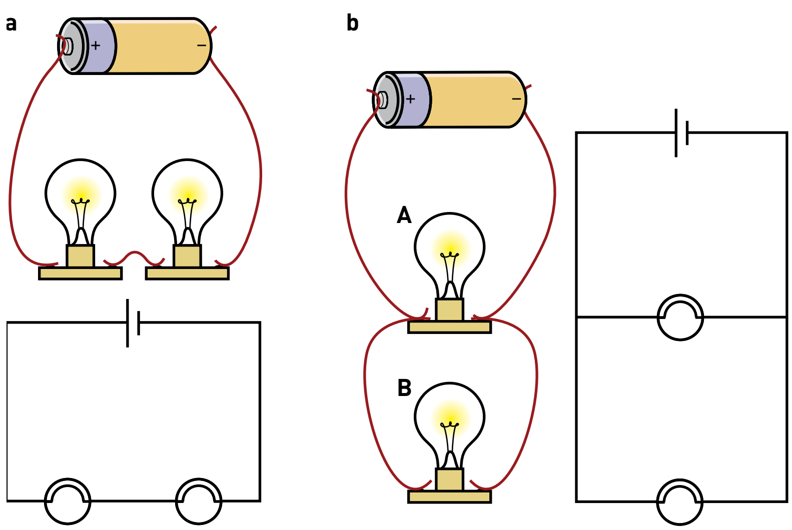


Figure 1 **a** In a series circuit, the current is the same anywhere in the circuit. **b** In a parallel circuit, the sum of the current going through globe A and globe B is equal to the total current from the battery.

CHALLENGE
7.5: Making series and parallel circuits
Go to page **212**.

Worked example 7.5: Calculating currents

If the current leaving a battery is 6 amperes (A), calculate the current travelling through two lamps if they are connected **a** in series, or **b** in parallel.

Solution

a If the lamps are connected in series, all the electrons flow through each lamp. Therefore, the current in each lamp is 6 A.

b If the lamps are connected in parallel, the electrons are divided between the wires. This means the current is divided equally between the lamps.

6 A ÷ 2 lamps = 3 A in each lamp

Batteries in series and in parallel

Batteries may be connected in series or in parallel, in a similar way to globes. When batteries are connected in series, each electron picks up a certain amount of energy as it passes through the first battery and then an additional amount as it passes through the second battery. This arrangement allows electrons to be given larger amounts of energy. For instance, a simple torch normally has two 1.5 V batteries connected in series.

As each electron passes through both batteries, it collects a total of 3.0 units of energy to light the torch globe

When batteries are connected in parallel, each electron passes through either one battery or the other. This means each electron collects the same amount of energy as it would from one battery on its own. The advantage of this arrangement is that the two batteries last longer than either one of them would in the same circuit on their own.

Short circuit

A **short circuit** occurs when a current (moving electrons) flows along a different path from the one intended. This can be caused by damaged insulation that usually surrounds the wires or by another shorter conductor, such as water, providing an easy path for the electrons. Electric charges will always take the path of least resistance. This means that large currents can flow through any short path or conductor that allows the electrons to move most easily. Short circuits are dangerous because they can also lead to wires heating up from the fast flow of electrons, causing damage or even fire.

Fuse

A **fuse** is a switch or thin piece of wire that burns up quickly when current flows too fast in a circuit. This causes a break in the circuit so the electrical energy stops flowing. This is to prevent damage to appliances from the high current, and to prevent electrocution.

short circuit
when electrical current flows along a different path from the one that was intended

fuse
a switch or wire that stops the flow of current if it starts moving too fast

Figure 3 A sudden increase in current will cause a fuse or safety switch to break the circuit. This stops the current from flowing and may prevent electrocution.

7.5 Check your learning

Retrieve

1 **Recall** the advantage of having a safety switch or fuse in the electric circuits of your house.

Comprehend

2 **Describe** how you could determine whether the globes in the party lights in Figure 2 are connected in series or parallel.

Analyse

3 **Contrast** the movement of current in a series circuit and a parallel circuit.

4 Three lamps were connected in series to a battery that produced a 12 A current. **Calculate** the current flowing in each lamp.

Apply

5 **Infer** how the household appliances are connected in your house (in series or in parallel). **Justify** your answer (by explaining how series and parallel circuits behave and providing an example that matches your explanation).

6 Double adaptors and power boards enable you to connect additional appliances to a power point. **Explain** whether the double adaptors or power boards are more likely to be series or parallel connections. **Justify** your answer.

7 An electrician wanted to connect four lamps to a 6 A source so that two lamps had a current of 6 A and the other two lamps had a current of 3 A. **Create** a circuit diagram to show a possible arrangement of the lamps the electrician could use.

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

SKILLS LAB
7.6A: Using Ohm's law to find resistance
Go to page **213**.

SKILLS LAB
7.6B: Understanding resistor colour codes
Go to page **214**.

7.6 Voltage is the difference in energy between two parts of a circuit

Learning intentions

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

- describe how voltage is shared in series circuits and in parallel circuits
- measure voltage using a voltmeter.

Key ideas

- Voltage is a measure of the difference in electrical potential energy carried by charged particles at different points in a circuit.
- Voltage can be measured using a voltmeter or multimeter in parallel to the circuit.
- Resistance is a measure of how difficult it is for current to flow through part of the circuit.

potential difference
voltage; the difference in the electrical potential energy carried by charged particles at different points in a circuit

voltage
potential difference; the difference in the electrical potential energy carried by charged particles at different points in a circuit

Voltage

Each charged particle has energy as it moves in an electric circuit. This potential energy can be transformed into sound as it moves through a speaker, or into light and heat if it moves through a globe. This means the charged particle (electron) has different amounts of energy before and after the speaker or globe. This difference in energy is called **potential difference** or **voltage**.

Voltage is measured by a voltmeter or a multimeter in the unit volts (symbol V). To measure the potential difference of a current, voltmeters are set in parallel across the two points in the circuit that you want to measure (Figure 1).

Batteries add energy to the charged particles. The amount of energy added by the battery can be determined by connecting a voltmeter in parallel to the battery. In a 1.5 V battery, each unit of charge (electron) receives 1.5 joules (symbol J) of energy as it passes through the battery.

In a series circuit, the potential energy contained by each electron must be divided between the different loads. This means a 12 V battery connected to two globes in series may transform 6 V of energy to each globe. If the two globes are connected in parallel, each electron moving in a globe is able to transform all the 12 V into light and heat.

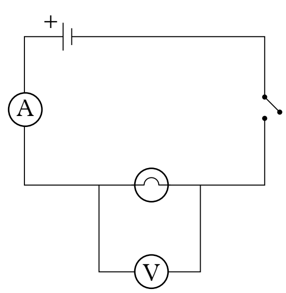


Figure 1 A voltmeter is used to measure voltage in a circuit.

Figure 2 Each unit of charge in this battery has 1.5 J of energy.

Resistance

The amount of current flowing in a circuit is determined by the **resistance** of the circuit. The electrical resistance of a material is a measure of how difficult it is for charged particles to move through. Electrons collide with the atoms in the wires and the various other components of a circuit, and some of their electrical energy is converted or transformed into heat. Most connecting wires are thick and made of good conductors.

Worked example 7.6A: Calculating voltage

If a 6 V battery is connected to two lamps, calculate the voltage that can be transformed in each lamp if they are connected **a** in series, or **b** in parallel.

Solution

a If the lamps are connected in series, the electrons must divide the voltage (potential energy) between the lamps.

Therefore, the voltage transformed in each lamp will be 3 V.

$6\text{ V} \div 2 \text{ lamps} = 3\text{ V in each lamp}$

b If the lamps are connected in parallel, the electrons will separate at the fork in the wires and carry all the energy to each lamp. This means the voltage (potential difference) transformed will be 6 V in each lamp.

EXPERIMENT

7.6C: Investigating Ohm's law
Go to page **215**.

This means they have very low resistance, and so hardly any energy is lost by the electrons. However, the wires in a toaster are designed so that a lot of the electrons' energy is transformed into heat – so much so that the wires glow red-hot and brown our toast.

Resistors are devices that are placed deliberately in circuits to control or reduce the size of the current. Resistance is measured by a multimeter in units called ohms (symbol Ω).

A potentiometer is another type of variable resistor with a dial that rotates. A light dimmer is a potentiometer, as is the temperature control on an oven.

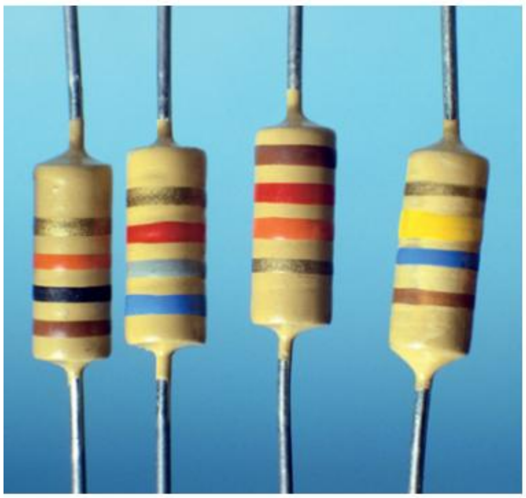


Figure 4 Many types of resistor are available. The resistance of carbon resistors is indicated by the coloured bands on their plastic case.

Ohm's law

Georg Ohm, a German physicist, discovered the relationship between voltage, current and resistance. Ohm found that the voltage drop across a fixed-value resistor is always directly proportional to the current through the resistor. This means that as the voltage goes down, the current will also go down. This relationship is known as Ohm's law and is written as:

$$V = IR$$

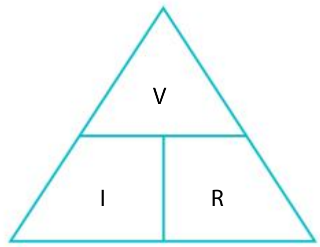


Figure 5 The Ohm's law triangle can be used to remember the equations for Ohm's law. To find resistance, cover the *R* – the other two letters show you the formula to use. The *V* is over the *I*, so $R = \frac{V}{I}$.

Worked example 7.6B: Calculating resistance

If a 9-volt battery produces 6 A of current, calculate the resistance of the circuit.

$$R = \frac{V}{I}$$

Solution

If $V = 9\,\text{V}$, and $I = 6\,\text{A}$, then

$$R = \frac{9\,\text{V}}{6\,\text{A}} = 1.5\,\Omega$$

Therefore, the resistance in the circuit is 1.5 Ω.

Figure 3 Metal wires are low resistance while the plastic coating has high resistance.

resistance
a measure of how difficult it is for the charged particles in an electric circuit to move

7.6 Check your learning

Retrieve

1 **Define** the term 'voltage'.

Comprehend

2 **Describe** the voltage across two lamps when they are connected:
 a in series
 b in parallel.

Analyse

3 **Identify** the three equations that can be obtained by rearranging the Ohm's law triangle.

4 **Calculate** the current flowing through a 44 Ω resistor when it has a voltage drop of 11 V across it.

5 **Calculate** the change in voltage across a 25 Ω resistor when a current of 50 mA (0.05 A) flows through it.

6 **Calculate** the value of a resistor that has a 'voltage drop' of 8 V across it when a current of 0.4 A flows through it.

7 Use Table 1 in Skills lab 7.6B to **identify** the value of a resistor that has three coloured bands of:
 a red, white, black
 b yellow, green, red
 c brown, blue, orange.

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

7.7 Visible light is a small part of the electromagnetic spectrum

Learning intentions

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

- list the classes of electromagnetic radiation and their average wavelengths
- explain how light behaves as a wave and how it behaves as a particle.

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

Key ideas

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

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

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

Electromagnetic spectrum

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

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

Transverse waves

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

The distance between two neighbouring peaks (rises) on a transverse wave is called the wavelength. It is the same as the distance between two consecutive troughs (dips) or between any two consecutive matching points on the wave (Figure 2). At a different wavelength, the nature of the light wave changes. In the region of visible light, this change of wavelength is seen as different colours.

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

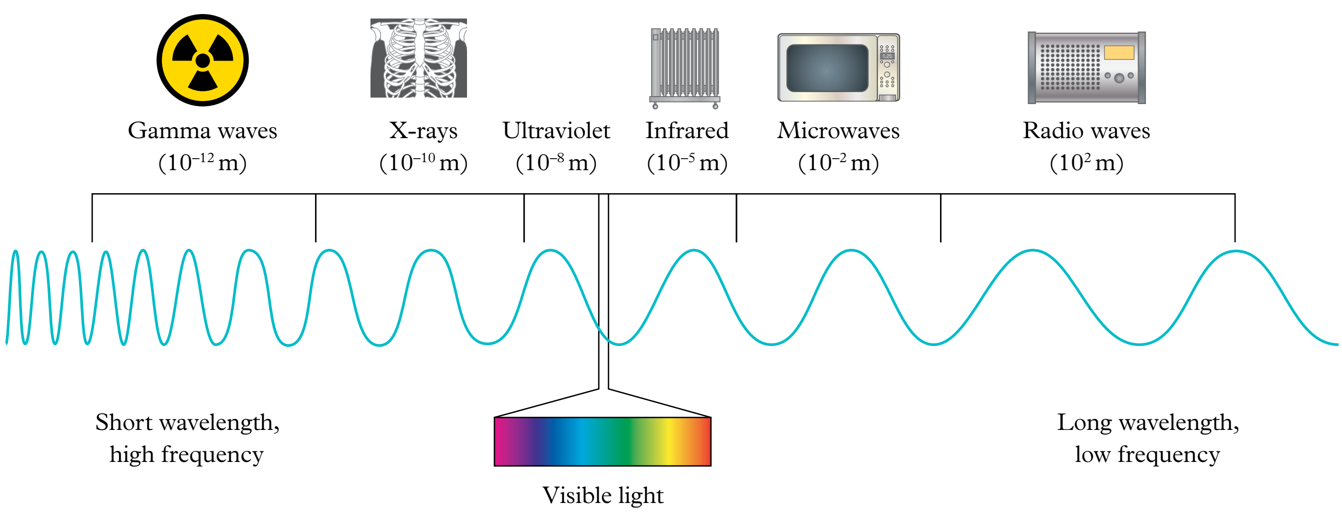


Figure 1 The electromagnetic spectrum

CHALLENGE
7.7: Modelling light waves
Go to page 216.

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

Speed of light

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

Particle or wave?

Experiments by early scientists provided two forms of evidence about how light behaves. In some experiments, light behaved as if it were a wave. Other experiments indicated that light was a particle.

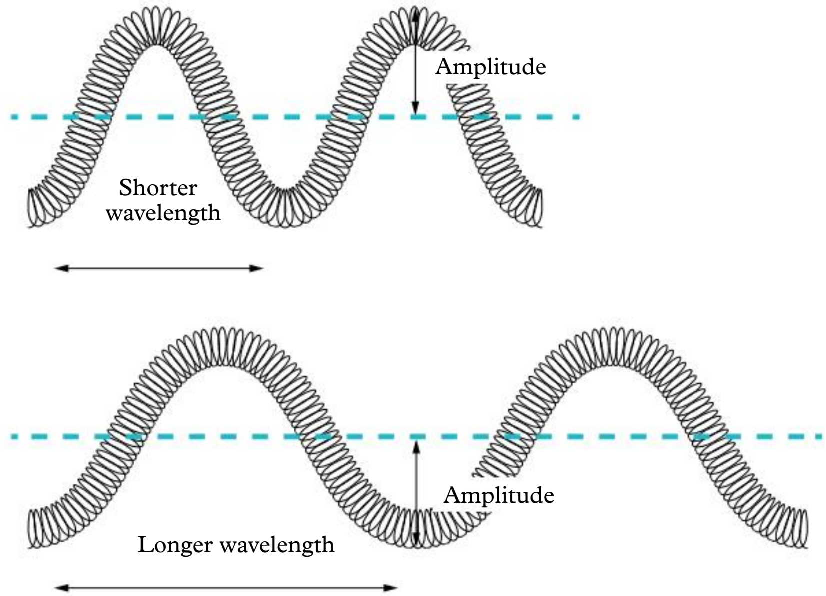


Figure 2 The wavelength of a wave is measured from any point on the wave (usually a peak or trough) to the next corresponding point.

Scientists now agree that light consists of a particle called a photon, which can move in a wavelike fashion. Just like a wave of water, it can bounce or reflect off surfaces and slow down if it travels through a thicker, denser material. Just like a separate particle, it can move by itself through space. This is how the light from the Sun can reach the Earth.

7.7 Check your learning

Retrieve

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

Comprehend

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

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

Analyse

4 **Compare** sound waves and light waves.

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

Apply

6 The relationship between wavelength and frequency is described as an inverse or reciprocal relationship. **Discuss** what is meant by 'inverse or reciprocal' as used in this statement.

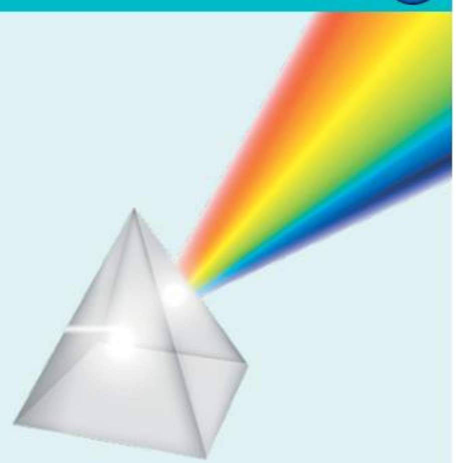


Figure 3 A prism is a transparent object in the shape of a triangle that separates white light into the colour spectrum.

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

SKILLS LAB
7.8A: Using a Hodson light box
Go to page **217**.

EXPERIMENT
7.8B: Reflection from plane mirrors
Go to page **218**.

7.8 Light reflects off a mirror

Learning intentions

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

- describe the characteristics of a virtual image
- demonstrate appropriate use of a Hodson light box.

Key ideas

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

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

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

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

When we look in a plane mirror (a flat mirror), we see a picture, or image, of ourselves. In the case of a plane mirror the image is always a **virtual image**. This means it cannot be captured on a piece of paper or on a screen as a movie projector does.

The image always forms where the light rays cross. The image we see in a plane mirror is also laterally inverted, or flipped sideways (Figure 2).

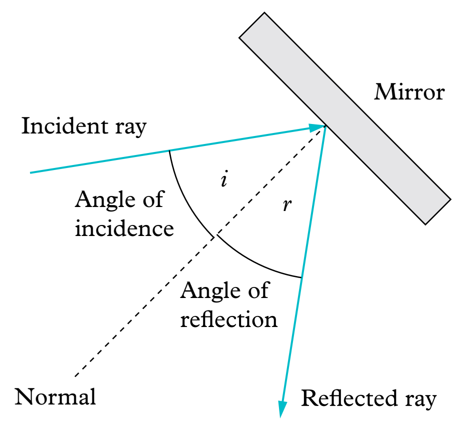


Figure 1 The angle of incidence (i) and the angle of reflection (r) are the same when light reflects off a mirror.

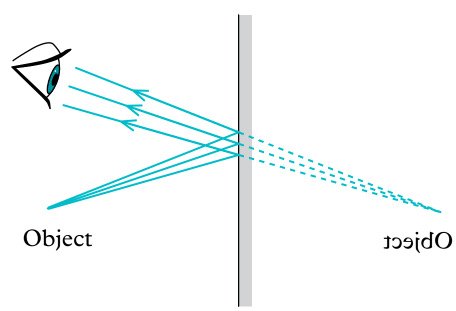


Figure 2 The image in a plane mirror is virtual, laterally inverted, the same size as the object and the same distance from the mirror.

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

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

opaque
not allowing light to pass through

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

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

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

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

CHALLENGE 7.8C: Mirror writing
Go to page 219.

CHALLENGE 7.8D: Using curved mirrors
Go to page 220.

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

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

Curved mirrors are not as predictable as plane mirrors. They can change the size and nature of the object's image.

Curved mirrors can be **convex**, where the centre sticks out, or **concave**, where the centre goes in, like a cave.

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

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

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

concave
refers to a lens or mirror that is thinner in the centre than at the ends

7.8 Check your learning

Retrieve

1 **Define** the terms 'transparent', 'translucent' and 'opaque' and **identify** one example of each.

2 **Recall** one use each of convex and concave mirrors.

Comprehend

3 **Explain** why light fittings are often translucent.

4 **Define** the normal, incident ray, angle of incidence, reflected ray and angle of reflection. Use a diagram to **illustrate** your definitions.

5 **Describe** a virtual image and provide an example of where you would see one.

Analyse

6 **Compare** concave and convex mirrors.

7 **Compare** plane mirrors and convex mirrors.

Figure 4 Virtual or real?

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

7.9 Light refracts when moving in and out of substances

Learning intentions

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

- describe the refraction of light through a convex and concave lens
- explain the difference between focus and virtual focus.

Key ideas

- Refraction is the bending of light as it enters or leaves a denser material at an angle.
- Light entering a denser medium bends towards the normal.
- Light entering a less dense medium bends away from the normal.

refraction
the bending of light as a result of speeding up or slowing down when moving into a medium of different density

medium
a substance or material through which light can move

refractive index
a measure of the bending of light as it passes from one medium to another

refracted ray
a ray of light that has bent as a result of speeding up or slowing down when it moves into a more or less dense medium

Refraction

Refraction is the bending of light as it passes at an angle from one transparent **medium** (i.e. substance or material) into another. For example, light bends when it travels from air into water, or from water into air. Often when light is bent or refracted, it can make objects appear distorted. You might be familiar with this effect when light bounces off a spoon sitting in water (Figure 1).

The amount that light bends depends on the distance between the particles of the medium.

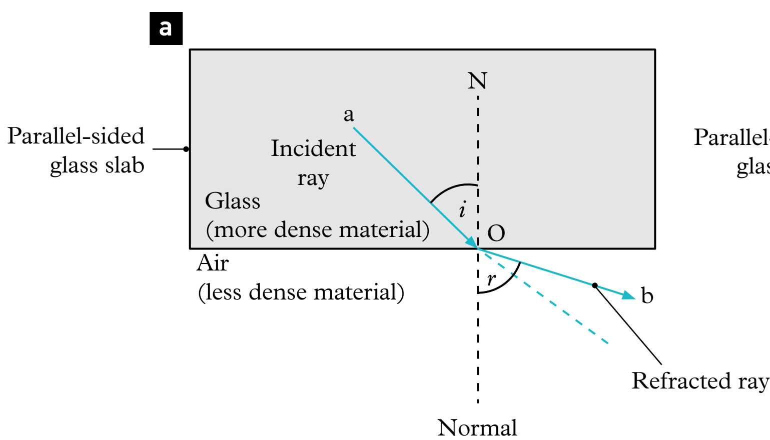
Figure 1 Water refracts light and distorts images.

This optical density or **refractive index** of the material has the symbol n. Water has a higher optical density than air and therefore has a higher refractive index. When a light ray in the air enters water, it slows down and bends closer to the 90° normal. This bent ray is called the **refracted ray** and its angle with the normal is the **angle of refraction**, r.

When the light ray leaves the denser medium (water) and moves into a less dense medium (air), it speeds up. When this happens, the light ray bends away from the normal.

Generally, dense liquids have a higher refractive index than less dense gases. Dense solids have a higher refractive index than less dense liquids. Light bends because it changes speed. The lower the refractive index, the faster the light travels in the medium.

The only time that light does not refract is when it enters a new medium along the normal (90° to the surface). It still changes speed, but there is no bending of the light.



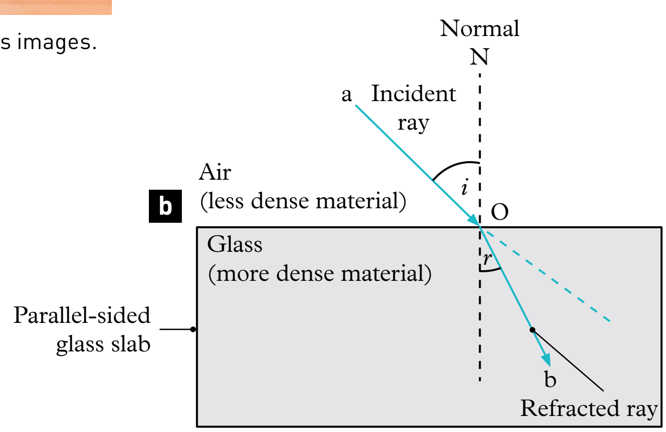


Figure 2 a Light entering a less dense medium bends away from the normal. **b** Light entering a denser medium bends towards the normal.

EXPERIMENT
7.9A: Bending of light
Go to page **221**.

EXPERIMENT
7.9B: Creating images with convex lenses
Go to page **222**.

Figure 3 Swimming pools and the ocean look shallower than they really are. The depth we see is the apparent depth. This person looks shorter in the water because light bends as it leaves the water making the bottom of the pool appear closer.

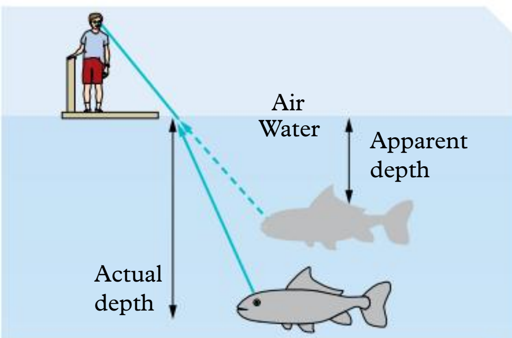


Figure 4 Refraction makes underwater objects appear closer to the surface than they really are. The fish looks closer to the surface than it really is because the light has left a denser medium.

Refraction in everyday life

Refraction explains a lot of everyday phenomena (Figures 3 and 4).

Lenses

A **lens** is usually a curved piece of transparent material, such as glass or plastic. Convex lenses are thicker in the centre than at the edges and concave lenses are thinner in the centre than at the edges. They work in a similar way to convex and concave mirrors.

Convex lenses cause light rays to **converge**, or focus. The **focus** (or focal point) is the point where the rays cross. The **focal length** is the distance from the focus to the middle of the lens (Figure 5).

Concave lenses cause light rays to **diverge** or spread out. The light rays appear to cross or focus on the other side of the lens. To find the focus, the diverging rays are followed back until they cross at the apparent light source (Figure 6). The focus can therefore be described as a **virtual focus** because the light rays do not really come from this point.

angle of refraction
the angle between a refracted ray and the normal (a line drawn at right angles to a refractive surface)

lens
a curved piece of transparent material

converge
(in relation to rays of light) to come together at a single point

focus
the point where rays of light cross

focal length
the distance between the centre of a lens and the focus

diverge
(in relation to rays of light) to move away from each other

virtual focus
the point at which a virtual image appears

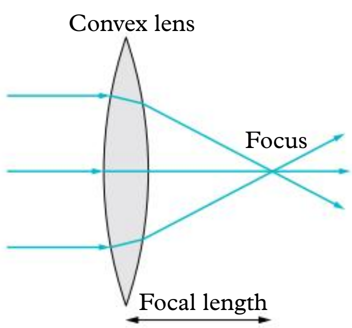


Figure 5 Parallel rays converge to a focal point with convex lenses.

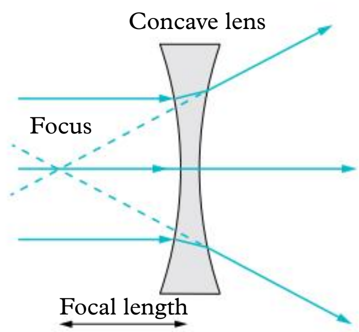


Figure 6 Parallel rays diverge from a focus through concave lenses.

7.9 Check your learning

Retrieve

1 Complete the following sentences by selecting 'towards' or 'away from'.

a Light travelling from a high refractive index to a low refractive index will bend (towards/away from) the normal.

b Light travelling from a low refractive index to a high refractive index will bend (towards/away from) the normal.

Comprehend

2 The refractive index of water is 1.33 and that of diamond is 2.42. Draw a diagram to **illustrate** how a light ray bends when it travels from water into diamond. Remember to use arrows to show the direction the light is moving.

3 The refractive index of glass is 1.52 and that of air is 1.00. Draw a diagram to **illustrate** how a light ray bends when it travels from glass into air.

4 **Describe** how convex and concave lenses are used.

Analyse

5 **Contrast** how light moves through convex and concave lenses.

6 **Compare** reflection and refraction.

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

7.10 Different wavelengths of light are different colours

Learning intentions

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

- describe how we see the colour of opaque and transparent objects
- explain how the primary colours of light can generate secondary colours of light.

Key ideas

- Visible light can be separated (dispersed) into the colours of the visible spectrum – red, orange, yellow, green, blue and violet.
- Each colour has a different wavelength and will refract different amounts to produce a rainbow.
- An object appears coloured when some wavelengths are absorbed, and others are reflected into our eyes.

visible spectrum
the variety of colours of wavelengths of light that can be seen by the human eye

dispersion
the separation of white light into its different colours

primary colours of light
the three colours of light (red, blue and green), which can be mixed to create white light

White light can be separated into an infinite range of different colours and shades, but there are generally considered to be six (or seven) basic colours – red, orange, yellow, green, blue and violet. Sir Isaac Newton discovered this concept, and popular belief has it that he included a seventh colour for good luck, called indigo, between blue and violet. This makes the colour sequence easy to remember as 'ROY-G-BIV'. This range of colours is called the **visible spectrum**. The process used to produce these colours is called **dispersion**.

Each colour of the visible spectrum has a different wavelength (the length of one complete cycle of a wave) and is refracted by a different amount when moving through mediums of different densities. This produces the separation of colours. A rainbow is an example of dispersion (and total internal reflection) where the white sunlight is separated (dispersed) into the separate colours (Figure 1).

Three of the six basic colours are called the **primary colours of light**. These are red, green and blue. This is because these three colours can be mixed to produce white light (Figure 2). When two of the primary colours are mixed, they form **secondary colours of light**. Red light and blue light make a red-blue light called magenta. Blue light and green light make an aqua or turquoise light called cyan. Green light and red light make yellow light. These rules are different for paints, so if you are an art student, you will need to think differently when considering mixtures of light compared to mixtures of paint!

If cyan light and red light are mixed, the result is white. When only two colours are needed to make white light, they are called complementary colours of light. This is because the cyan light already contains blue and green, so if we add red light, we effectively have the three primary colours, which we already know make white.

Figure 1 A rainbow shows all of the colours in the visible spectrum.

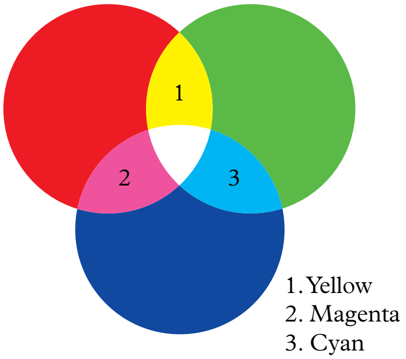


Figure 2 Where the red, green and blue lights overlap, white light is produced. The secondary colours are formed by the overlap of two of the primary colours.

EXPERIMENT
7.10: What colour is it?
Go to page 223.

Colour of opaque objects

So, why do coloured objects appear coloured? When white light (or sunlight) falls on an opaque object, the energy of some colours may be reflected while others are absorbed (or soaked up or subtracted from the white light) (Figure 3). The colour the object appears to be depends on the mix of colours that reflects into our eyes. In most cases, it is easier to consider white light as just made up of red, green and blue light energy.

If some energy colours are absorbed and some are reflected, the object will appear to be the colour of the mix it reflects. This rule is the same for objects illuminated by coloured light. So, a red top appears red because red light is reflected from the red surface to our eye. Grass is green because the red and blue wavelengths are absorbed and the green wavelength is reflected back to our eyes.

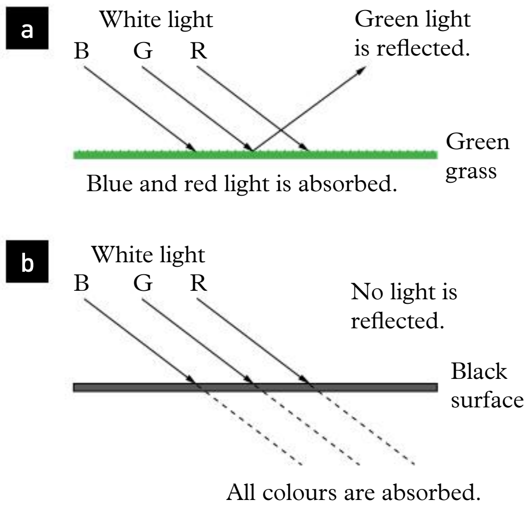


Figure 3 **a** A green surface reflects green light and so looks green. **b** A black surface absorbs all colours and so looks black. No colours are reflected.

Colour of transparent objects

Transparent objects, such as the coloured **filters** in the Hodson light box kits (see Experiment 7.10), or coloured cellophane, **transmit** (allow to pass) and absorb colours in the same general way that blue objects appear blue to us. If the blue colour is transmitted (passes through) while the red and green colours are absorbed, then the filter appears to be blue. Alternatively, a red filter appears red because the blue light and green light are absorbed and red passes through. Therefore, we see the red light from the filter.

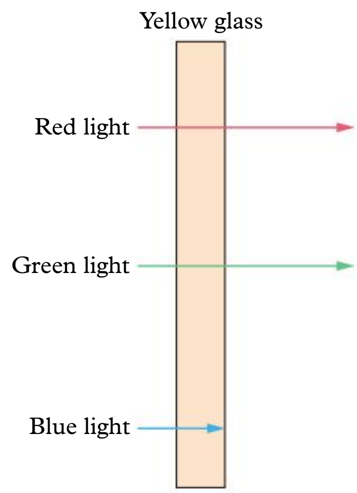


Figure 4 A filter that transmits red and green light and absorbs blue light will appear yellow (the secondary colour that comes from red and green).

secondary colours of light
the colours of light (magenta, cyan and yellow) that result from the mixing of two primary colours of light

filter
a transparent material that allows only one colour of light to pass through

transmit
to allow light to pass through

7.10 Check your learning

Retrieve

1 **Identify** the colour that is produced when magenta and green lights are mixed.

Comprehend

2 If white light is a mixture of all the primary colours of light, **explain** what black is.

Analyse

3 **Contrast** how light moves when hitting a filter and when hitting an opaque object.

4 **Contrast** the primary and secondary colours of light.

Apply

5 **Describe** what you would see if you looked at white light through a yellow filter. **Justify** your answer (by describing what happens to each of the primary colours of the white light when they hit the yellow filter).

6 **Describe** the colour that a green surface will appear in red light. **Justify** your answer by explaining what happens when the red light hits the green surface.

Figure 5 The colour of light

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

7.11 The electromagnetic spectrum has many uses

Learning intentions

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

- define critical angle, total internal reflection and optic fibre
- describe how optic fibres and microwave ovens work.

Key ideas

- Total internal reflection occurs when a light ray passes into a less dense medium at a particularly large angle.
- Optic fibres use total internal reflection to pass data.
- Other forms of the electromagnetic spectrum, such as microwaves, are used for communication and for cooking food.

Video 7.11
The electromagnetic spectrum

Total internal reflection

Many optical instruments, such as cameras, microscopes and some telescopes, use lenses, but several use prisms to reflect light. A prism is a block of glass. When light passes from one medium (glass) to a less dense medium (air), it is refracted away from the normal. As the angle of the light (incidence) increases, the refracted ray may be refracted away from the normal so much that it travels at an angle of 90° to the normal. This means the refracted ray moves along the surface edge between the two media, known as the interface. The angle of incidence at which this occurs is called the **critical angle** (symbol i_c).

If the angle of incidence is increased more than the critical angle, the light has nowhere to go and is reflected back into the dense medium. This phenomenon is known as **total internal reflection**. This only occurs when light attempts to travel from a more dense medium (glass) into a less dense medium (air) and only for angles greater than the critical angle.

critical angle
the angle of light that causes the reflected ray to move along the edge between two materials

total internal reflection
the complete reflection of a light ray when it passes from a more dense to a less dense material at a large angle; the ray is reflected back into the dense medium

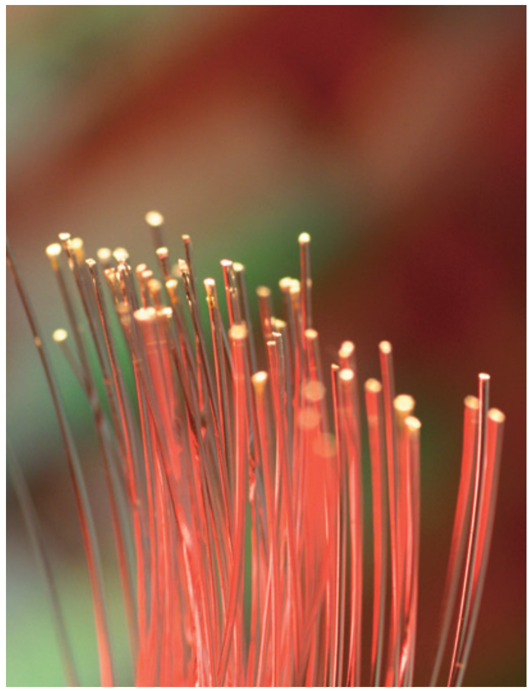


Figure 2 Optic fibres are used to carry digital light signals and have various applications.

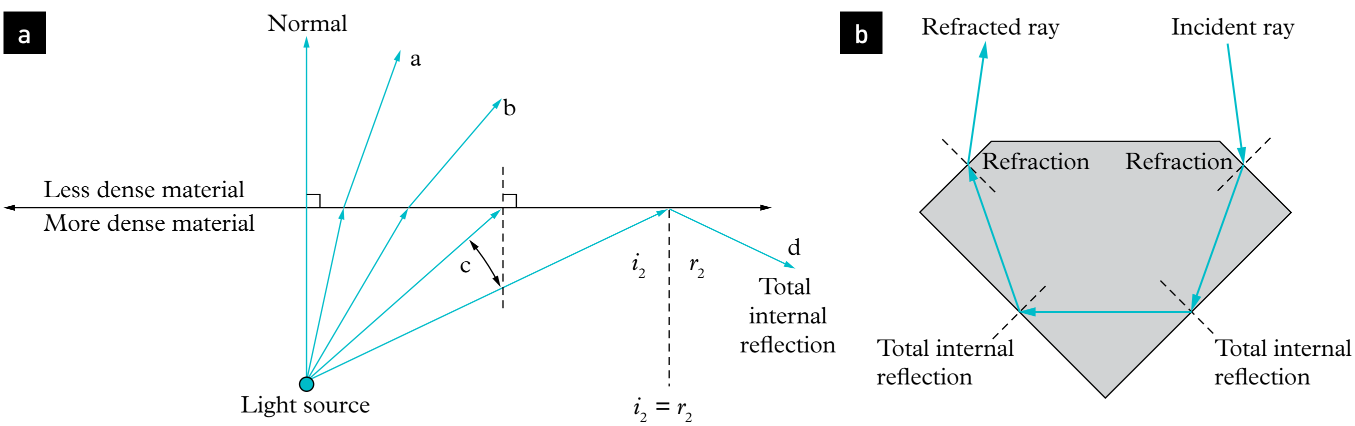


Figure 1 a Rays a and b are refracted because the angle of incidence is less than the critical angle. Ray c occurs when the critical angle is reached. Ray d is reflected when the angle of incidence is greater than the critical angle. **b** Total internal reflection

EXPERIMENT

7.11: What is the wavelength of a microwave?
Go to page **224**.

Using total internal reflection

Optic fibres have revolutionised communication systems. Instead of relying on copper wires to carry electrical signals, we now use bundles of optic fibres to carry light signals for landline telephone calls, the internet and the NBN (National Broadband Network). An **optic fibre** is a very thin fibre of glass or plastic that carries light that reflects (total internal reflection) off the internal surface continually. By sending the information as controlled pulses of light, a single fibre less than a millimetre wide can carry thousands of landline telephone calls and millions of bits of data.

The advantages of optic fibres over copper wire are less signal loss, greater carrying capacity and immunity to electromagnetic interference. This means long distances can be covered with fewer repeater (or booster) stations. A single optic fibre carries much more data than a copper cable, so optic fibres save space, and crossed messages (a form of interference) cannot happen. Optic fibres do not generate heat like the current in a copper wire and are non-electrical, so they don't pose a fire risk and can be used around high voltages.

Microwaves

Microwaves are one small part of the electromagnetic spectrum. The wavelengths of microwaves are usually 1 mm to 1 m in length. Microwaves have many uses from communication (mobile phones) to cooking, from global positioning systems (GPS) to radar. Microwaves can be focused into narrower beams than radio waves. This allows them to be used for person-to-person communication on Earth or even between Earth and the space station.

Microwave ovens

The electromagnetic waves in a microwave oven provide energy to make the water molecules in food move. The increased movement (kinetic energy) of the water molecules causes friction between the other molecules in the food. This friction between all the molecules causes the food to heat up.

optic fibre
a thin fibre of glass or plastic that carries information/data in the form of light

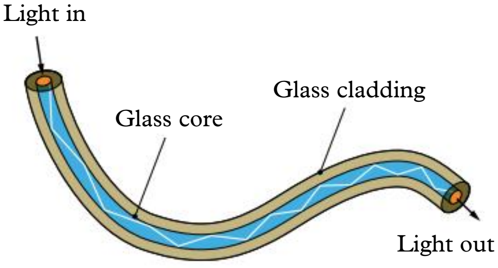


Figure 3 Light zigzags along inside an optic fibre at the boundary of the core and the cladding.

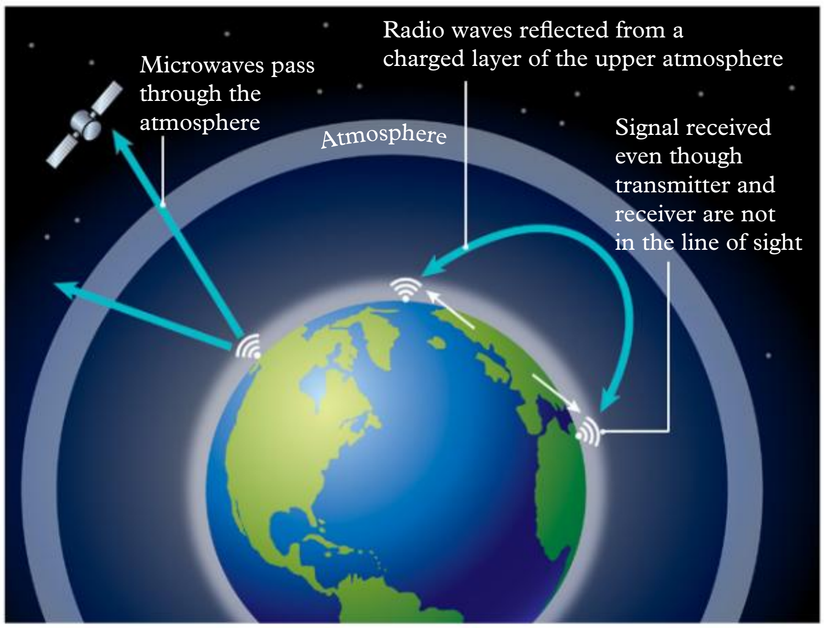


Figure 4 Electromagnetic waves with different wavelengths behave differently in the Earth's atmosphere.

7.11 Check your learning

Comprehend

1 **Describe** when and how total internal reflection occurs.

2 **Describe** why optic fibres are better for telecommunications than copper wire.

3 **Explain** why the amount of water in a food is important when cooking in a microwave.

Analyse

4 **Contrast** total internal reflection and the reflection from a plane mirror.

Apply

5 **Discuss** why total internal reflection cannot occur for light passing from a less dense material into a denser material.

6 **Investigate** one other use for other forms of electromagnetic waves.

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

CHAPTER 7 REVIEW

PARTICLES AND WAVES

Retrieve

1 **Identify** which of the following terms can be used to describe sound waves.
- A transverse waves
- B electromagnetic waves
- C microwaves
- D longitudinal waves

2 **Identify** which of the following is correct.
- A Sound waves travel faster than light waves.
- B Sound travels faster in air than in water.
- C Light travels faster than sound.
- D Sound can travel through space.

3 **Identify** the units of voltage, current and resistance, respectively.
- A amps, ohms, volts
- B ohms, volts, amps
- C volts, amps, ohms
- D volts, ohms, amps

4 **Define** the term 'frequency' of sound. **Identify** its unit.

5 **Identify** the circuit in Figure 1 as either a parallel circuit or a series circuit.

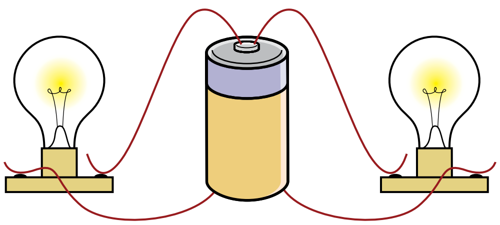


Figure 1 Identify the circuit.

6 Complete this paragraph by **identifying** the missing words. The first letter of each missing word is given.

Sound is created by v________. The v________ create c________ and r________ due to the movement of the particles as the sound w________ passes through. The w________ travels through the substance and is known as a l________ wave. The greater the vibration, the higher the v________ of the sound, which means it sounds l________. Sound waves must have a m________ to pass through.

Comprehend

7 **Explain** why astronauts could shout at each other with their helmets touching if the radio communication broke down on the Moon.

8 **Describe** how current moves in a parallel circuit.

9 Figure 2 shows a block of ice melting.
- a **Describe** what is happening to the molecules as the ice melts. Draw a diagram to **illustrate** your answer.
- b **Explain** where the energy to melt the ice comes from. **Explain** how the energy is transferred to the molecules of ice.

Figure 2 A block of ice melting

10 Butchers sometimes use red lights to illuminate their meat in the shop window. **Explain** why they might choose this colour.

11 **Explain** why sound travels faster in solids than in air.

12 **Describe** the difference between the primary colours of light and the primary colours of paint.

13 **Explain** how pitch and frequency of sound are related.

14 **Describe** the conditions that can slow the speed of light.

15 **Describe** how light moves in an optic fibre.

16 **Describe** the appearance of the Australian flag when viewed in:
- a blue light
- b red light
- c green light.

Analyse

17 **Consider** why scientists are happy to refer to thermal energy transfer as heating, even though in every case something is being cooled.

18 **Compare** current and voltage.

19 **Compare** transverse waves and longitudinal waves.

20 **Compare** the reflection of light and the refraction of light.

21 **Compare** conduction and convection.

22 **Calculate** the current flowing through a 30 Ω resistor when it has a voltage drop of 12 V across it.

23 **Calculate** the voltage drop across a 50 Ω resistor when a current of 25 mA flows through it.

Apply

24 A student claimed that black is not a colour. **Evaluate** their claim (by explaining how an object can appear black, defining what is a colour of light, and deciding if the student is correct).

25 First Nations peoples use the didgeridoo for many important ceremonies. **Discuss** why longer didgeridoos produce sounds that are lower in pitch than short didgeridoos. (HINT: Consider the length of the sound waves produced by each didgeridoo.)

Figure 3 Didgeridoos of different lengths

26 **Discuss**, in terms of kinetic energy of particles, why:

- **a** convection can only occur in liquids and gases and not solids
- **b** when energy transfers by convection or conduction, the substance through which the energy transfers is also heated
- **c** a gas makes a better thermal insulator than a solid
- **d** neither convection nor conduction is a way of transferring energy through a vacuum.

27 First Nations peoples have used possum, kangaroo and wallaby skin coats to keep themselves warm. Traditionally, the fur was worn with the fur facing towards the body to reduce heat loss. Use your understanding of the transfer of thermal energy to **discuss** the effectiveness of this strategy.

28 Power lines carry electricity from power stations to cities and towns. They experience a voltage loss due to the high resistance along the lines according to Ohm's law. **Propose** how the quantities of I and R could be changed to minimise this voltage loss due to resistance. (HINT: Consider how to decrease the resistance.)

Figure 4 Power lines carry electricity from this power station to towns and cities.

Critical and creative thinking

29 Table 1 shows the speed of sound at different temperatures.

a Using graph paper, **create** a graph of the speed of sound (vertical axis) at various air temperatures (horizontal axis). Start the scale at 320 m/s on the vertical axis.

b **Describe** what happens to the speed of sound as the temperature increases.

c Use your graph to **identify** the speed of sound at 5°C.

d Use your graph to **identify** the temperature of the air if the speed of sound is 351 m/s.

Table 1 The speed of sound at different temperatures

Air temperature (°C)	Speed of sound (m/s)
0	330
10	336
20	342
30	348
40	354

30 Astronauts in space can still see each other even if they cannot hear each other.

a Use this information to **compare** how light and sound travel.

b **Determine** what this tells us about the ability of light energy to travel through outer space.

31 **Investigate** the differences and similarities between audible sound, ultrasound and infrasound. Display your answer using a Venn diagram.

32 Use your understanding of current and voltage to **create** a model of the flow of electricity through a circuit. You might use people or even an animation as your model.

Research

33 Choose one of the following topics for a research project. A few guiding questions have been provided, but you should add more questions that you wish to investigate. Present your report in a format of your own choosing, but one component of your report must include a demonstration of sound (for example, if you make an instrument, it needs to be played). In a multimedia presentation, sound must be part of the presentation. If you interview someone as part of your research, you must present a taped recording of your interview along with your report.

» Supersonic planes

Identify what 'supersonic sound' means.

» Contrast a supersonic jet and a normal jet aircraft.

» Describe one of the problems with supersonic planes.

» Describe why the Concorde was removed from air travel service.

Figure 5 The Concorde has been removed from air travel service.

» Night vision goggles

Night vision goggles allow soldiers to see at night and spot the enemy before they are spotted themselves. They give an army a tactical advantage.

» Describe how the goggles work.

» Identify the limitations of these goggles (i.e. will they work in a totally dark environment? Do they have any disadvantages to the soldiers operating them?)

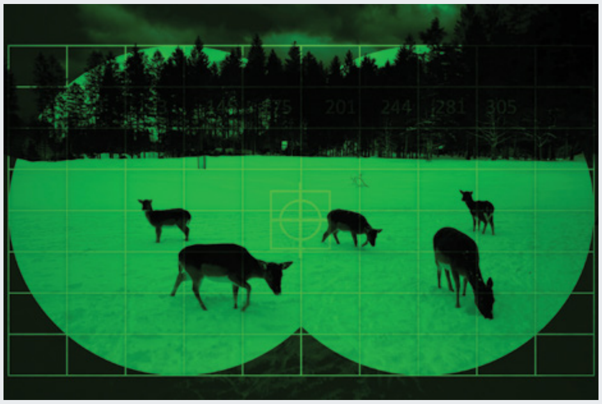


Figure 6 View of deer and forest through night vision goggles

Chapter checklist

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

	I can do this.	I cannot do this yet.
• Explain how heat energy is transferred by conduction and convection in terms of the motion of particles.	☐	☐ Go back to Topic 7.1 'Heat can be transferred by convection and conduction'. Page 136
• Describe the motion of molecules in a longitudinal wave.	☐	☐ Go back to Topic 7.2 'Vibrating particles pass on sound'. Page 138
• Explain why sound does not travel through space. • Describe how the transmission of sound can be affected by the density of the medium it travels through.	☐	☐ Go back to Topic 7.3 'Sound can travel at different speeds'. Page 140
• Describe the difference between static electricity and electric current. • Identify the key components of an electric circuit.	☐	☐ Go back to Topic 7.4 'Electricity is the presence and flow of charged particles'. Page 142
• Describe the differences in arrangement of series and parallel circuits. • Measure current using an ammeter.	☐	☐ Go back to Topic 7.5 'Current can flow through series and parallel circuits'. Page 144
• Describe how voltage is shared in series circuits and in parallel circuits. • Measure voltage using a voltmeter.	☐	☐ Go back to Topic 7.6 'Voltage is the difference in energy between two parts of a circuit'. Page 146
• List the classes of electromagnetic radiation and their average wavelengths. • Explain how light behaves as a wave and how it behaves as a particle.	☐	☐ Go back to Topic 7.7 'Visible light is a small part of the electromagnetic spectrum'. Page 148
• Describe the characteristics of a virtual image. • Demonstrate appropriate use of a Hodson light box.	☐	☐ Go back to Topic 7.8 'Light reflects off a mirror'. Page 150
• Describe the refraction of light through a convex and concave lens. • Explain the difference between focus and virtual focus.	☐	☐ Go back to Topic 7.9 'Light refracts when moving in and out of substances'. Page 152
• Describe how we see the colour of opaque and transparent objects. • Explain how the primary colours of light can generate secondary colours of light.	☐	☐ Go back to Topic 7.10 'Different wavelengths of light are different colours'. Page 154
• Define critical angle, total internal reflection and optic fibre. • Describe how optic fibres and microwave ovens work.	☐	☐ Go back to Topic 7.11 'The electromagnetic spectrum has many uses'. Page 156

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

pro

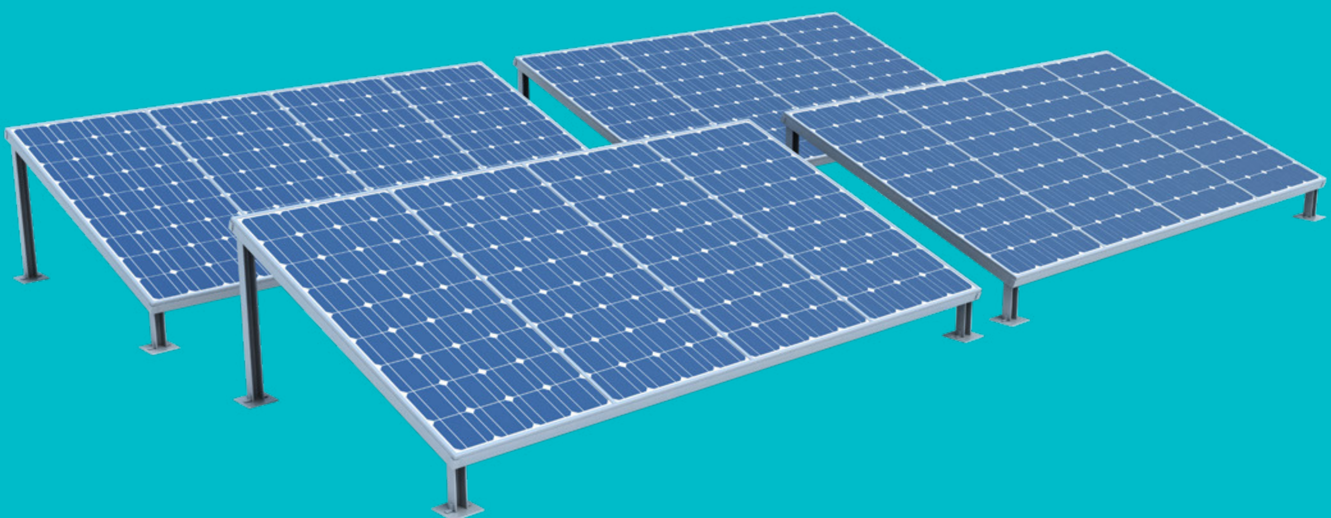
Quizlet
Play a Quizlet game to test your knowledge.

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

CHAPTER

8

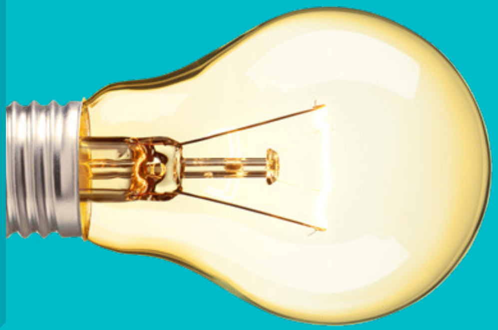
ENERGY EFFICIENCY



8.1

Energy cannot be created or destroyed

> Explain the law of conservation of energy.
> Describe the relationship between waste energy and the energy efficiency of a device.
> Use the efficiency formula to calculate unknown values.



8.2

Sankey diagrams can represent energy efficiency

> Use Sankey diagrams to show energy inputs, changes and outputs.
> Interpret Sankey diagrams.

8.3

Energy efficiency can reduce energy consumption

> Describe examples of energy-efficient practices used by First Nations peoples.
> Describe examples of features in buildings that improve energy efficiency.

8.4

Athletes need to be energy efficient

> Identify the energy transfers and transformations involved in archery and pole vaulting.
> Explain how becoming more energy efficient can improve performance in a sport.

What if?

Bouncing ball

What you need:

Basketball or tennis ball, tape measure

What to do:

1 Drop the ball.
2 Notice the volume of the sound the ball makes when it hits the ground.
3 Measure how high the ball bounces.

What if?

» What if the ball were dropped from a greater height? Would it bounce higher? Would the sound be louder?
» What if the ball were bounced instead of dropped?
» What if the ball were bounced with greater force?

8.1 Energy cannot be created or destroyed

Learning intentions

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

- explain the law of conservation of energy
- describe the relationship between waste energy and the energy efficiency of a device
- use the efficiency formula to calculate unknown values.

Key ideas

- The law of conservation of energy states that energy cannot be created or destroyed.
- When energy is transformed, waste energy is produced.
- Efficient energy transformations produce less waste energy.

Energy cannot be created or destroyed

People have been fascinated with energy for thousands of years, from the heat energy released in the earliest human-generated fires, to the energy that allows us to reach the Moon and beyond. In the previous chapter, you examined the different models of heat, sound, electricity and light energy. There is one law that is consistent across all forms of energy: energy cannot be created or destroyed.

Law of conservation of energy

When energy is transformed or transferred, the amount of energy that goes in must always be the same as the energy that goes out. The total energy remains constant, even if the type of energy changes – what goes in must come out!

This is considered the **law of conservation of energy**. No energy can be created or destroyed. The energy at the end must be equal to the energy present at the beginning. When you lift an object up in the air, you add gravitational potential energy. This energy did not just appear. The kinetic energy of your hand was conserved and transformed into the gravitational energy of the object. When the object is dropped, the energy is not destroyed. The gravitational energy is once again transformed into kinetic energy as it falls.

Energy efficiency

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

Energy efficiency is a calculation of the percentage of useful energy transformed.

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

Take the trampoline example in Figure 1. The input energy was 500 units and the useful output energy was 400 units. This means that the trampoline is 400 ÷ 500 × 100 = 80% efficient.

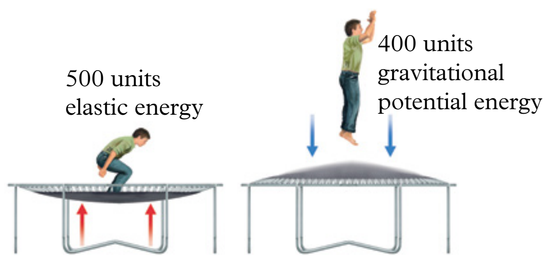


Figure 1 Five hundred units of energy are stored in the springs of the trampoline. At the highest point, the jumper has 400 units of gravitational potential energy. Where have the 100 'missing' units gone?

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

Worked example 8.1 shows how to calculate energy efficiency.

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

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

Worked example 8.1: Calculating energy efficiency

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

a Calculate the energy efficiency of the tennis ball.

b Calculate the waste energy as the tennis ball bounced.

Solution

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

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

$$\text{Efficiency} = \frac{\text{Useful energy output}}{\text{Energy input}} \times 100$$
$$= \frac{90}{150} \times 100$$
$$= 60\%$$

The tennis ball had an energy efficiency of 60%.

b The ball is 60% efficient.

$$\text{Waste energy} = \text{Energy input} - \text{Useful output energy}$$
$$= 100\% - 60\%$$
$$= 40\%$$

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

Heat and sound waste energy

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

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

Figure 3 Dropping a glass bottle onto the ground generates and releases sound energy, producing a large shattering noise.

8.1 Check your learning

Retrieve

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

2 **Define** ‘energy efficiency’.

Comprehend

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

Analyse

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

b For the rubber band in part **a**, **calculate** its percentage efficiency if 7 units of kinetic energy were produced. **Describe** where the remaining 3 units of energy have gone.

5 **Identify** and **describe** the by-product energy transformations for a car.

Apply

6 A student claimed energy was lost when they bounced a ball. **Evaluate** the student’s statement (by describing the law of conservation of energy, describing how this law applies to the student’s statement, and deciding if the statement is correct).

Quiz me

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

8.2 Sankey diagrams can represent energy efficiency

Learning intentions

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

- use Sankey diagrams to show energy inputs, changes and outputs
- interpret Sankey diagrams.

Key idea

- The conservation of energy can be represented in a Sankey diagram.

Drawing energy efficiency

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

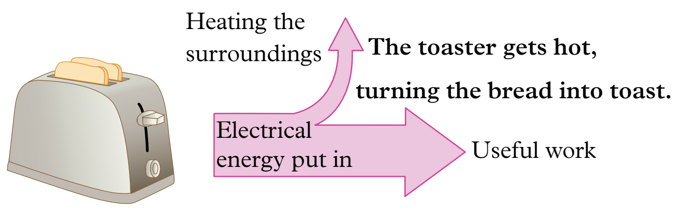


Figure 1 A Sankey diagram of energy transfer in a toaster

Sankey diagrams

A Sankey diagram is a type of flow diagram. You learnt about flow diagrams in Year 8. Sankey diagrams are used to represent the efficiency of energy transfers and transformations. Each Sankey diagram has a series of lines of different widths. The widths of the lines represent the amount of energy that flows in and out of a system.

Let's look at the transfer and transformation of energy in toasters. Toasters use heating elements to convert electrical energy into thermal energy. Heating elements are made of wires that heat up without melting when electricity flows through them. These wires are not good conductors of electricity. If the wires resist the flow of charged particles and make it more difficult to move, then more electrical energy is transformed into thermal energy. The thermal energy is then passed to the air, which then passes the heat to the bread, toasting it. This transfer of energy can be represented in a Sankey diagram (Figure 1).

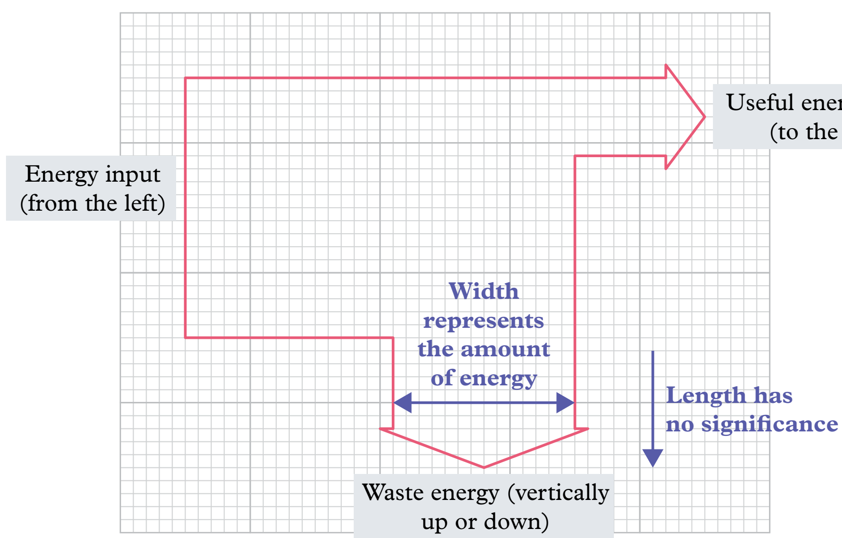


Figure 2 Key steps for drawing a Sankey diagram

Drawing a Sankey diagram

Sankey diagrams have three main parts, the input energy, the waste energy and the output energy. The input energy is shown at the start of the arrow on the left-hand side of the diagram. The useful output energy is shown with an arrowhead travelling straight on to the right-hand side. The waste energy is usually shown by another arrowhead travelling either up or down on the diagram. Sankey diagrams are usually drawn on graph paper so that the width of the arrow can accurately represent the amount of energy (Figure 2).

Sankey diagrams can also be used to represent more complex energy transitions.

Worked example 8.2 shows the process of drawing a Sankey diagram.

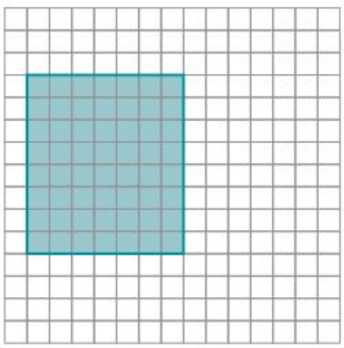
Worked example 8.2: Drawing a Sankey diagram

A kettle has an input of 800 J of electrical energy. 600 J of thermal energy is used to heat the water while 200 J of thermal energy heats the surrounding air. Draw a Sankey diagram to represent this energy transfer.

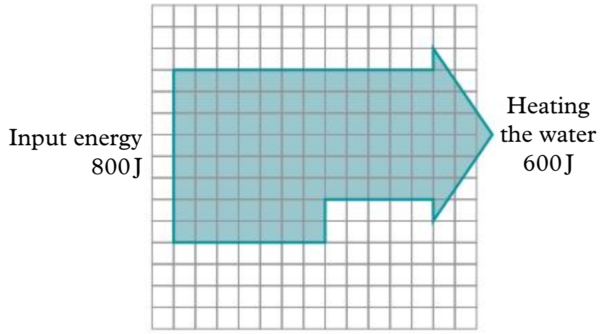
Solution

Before starting your diagram, you will need to decide the scale you will use on graph paper. It is usually easiest to have 1 square being equal to a simple number. In this case 1 square = 100 joules.

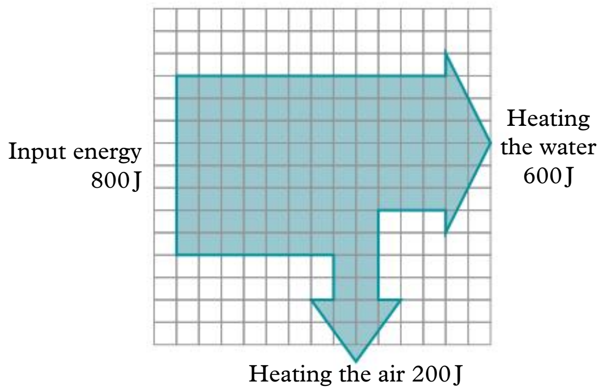
The input energy is 800 J (8 squares). Colour in 8 squares down the graph paper. This can be made as wide as you need (leaving room for the waste energy later). Add a label to show the input energy.



The useful thermal energy that heats the water is 600 J. Extend six coloured squares to a final output arrow. Add a label.



The waste energy (heating of the air surroundings) is 200 J. This means a line 2 squares wide needs to extend down. Add an arrowhead and label.



This is now a Sankey diagram of the energy input and output of the kettle.

8.2 Check your learning

Retrieve

1 **Identify** the three key parts of a Sankey diagram.

Comprehend

2 Use a Sankey diagram to **represent** the energy transfers and transformations of a rubber band that starts with 10 units of elastic energy and produces 6 units of kinetic energy, 3 units of waste heat and 1 unit of waste sound.

Analyse

3 The Sun provides 400 J of light energy to a plant. The plant uses the light to store 100 J of chemical energy. **Calculate** the amount of waste energy from this process.

4 A student claimed a fan heater was inefficient due to energy lost as sound.

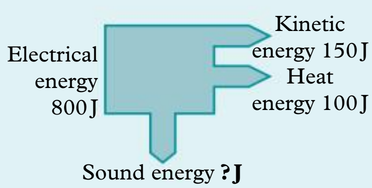


Figure 3 Sankey diagram for a fan heater

a **Explain** why thermal energy and kinetic energy is considered 'useful' in a fan heater.

b Use the Law of Conservation of Energy to **explain** why sound energy is not 'lost'.

c Use Figure 3 to **calculate** the amount of sound energy generated.

5 **Calculate** the amount of electrical energy required by the television in Figure 4.

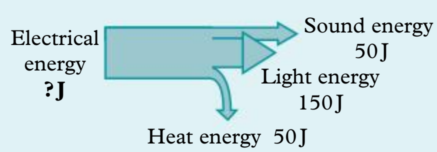


Figure 4 Sankey diagram for a television

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

8.3 Energy efficiency can reduce energy consumption

Learning intentions

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

- describe examples of energy-efficient practices used by First Nations peoples
- describe examples of features in buildings that improve energy efficiency.

Key ideas

- Understanding how waste energy is formed allows it to be minimised.
- Waste energy can be useful.
- Insulation prevents the transfer of thermal (heat) energy.
- Knowledge and understanding of energy transformations is not limited to scientists.

Useful waste energy

Most energy transformations can result in thermal waste energy. For thousands of years, First Nations peoples have used their understanding of the way energy is transferred and transformed to develop energy efficient ways to generate heat and to cook food using this thermal waste energy.

Generating fire

The ability to generate fire is a skill used across many First Nations cultures. The fire drill method is an example of using what may be considered waste energy to cook or to stay warm. It involves pushing the blunt end of a long, thin drill stick into the flat surface of wood. As the drill stick is rubbed between the hands, the kinetic energy causes it to twist into the flat wood.

The friction between the two pieces of wood produces thermal waste energy in the flat wood. Eventually the wood becomes so hot that a combustion reaction is started.

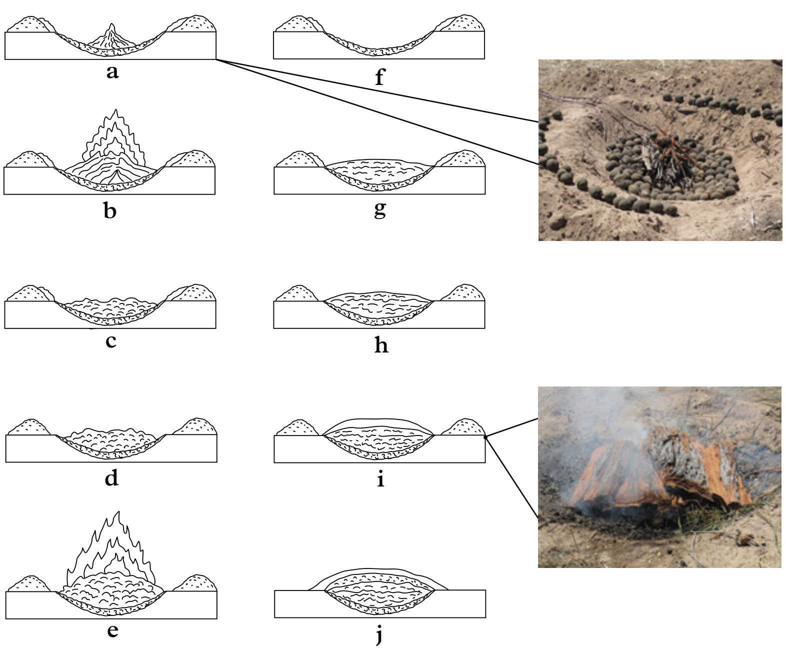


Figure 1 Recreation of a traditional ground oven

Cooking food

One role of archaeologists is to develop an understanding of traditional methods used by First Nations peoples to cook food. With the permission of the Barengi Gadjin Land Council Aboriginal Corporation which represents the Traditional Owners of the Jadawadjali language group in western Victoria, archaeologists set out to recreate a traditional ground oven. They dug a large pit, 25 cm deep in the earth and lined the base of the pit with spheres made of clay and sand. On top of the spheres, a fire was slowly built up until it burnt strongly for 1 hour (Figures 1a–e). When the fire died down to glowing coal, half the coals and spheres were removed (Figure 1f). Wet reeds were placed on top of the remaining coals and clayey spheres (Figure 1g) before the edible roots of *Microseris scapigera* (yam daisy) were placed on top of the reeds. The remaining hot coals and spheres (Figure 1h) were placed on top of the roots before being covered with large sheets of stringy bark (Figure 1i) and sand (Figure 1j). The food was cooked overnight. This process of using the reeds, stringy bark and sand to insulate the heat with the roots reduced the loss of heat and increased the efficiency of the ground oven.

Heating and cooling your house

You probably use electricity or gas to run heating or cooling systems at home. In a hot environment, energy is needed to remove the heat from inside your home, allowing it to cool down.

CHALLENGE

8.3: Design an energy-efficient house
Go to page 225.

The warm air inside the house is moved over cool pipes in an air conditioner. The thermal energy of the house air is passed to the refrigerant inside the pipes and is then carried outside the house. If the house is well designed, thermal energy remains outside and the house stays cool.

Home design features

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

Insulation

Lining the inside of the walls, floors and roof of your house can ensure that heat is not transferred between the outside air and the inside of the house. This keeps the heat inside on a cold day and outside on a hot day.

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

Window awnings

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

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

Verandas

Verandas work much like awnings, but also prevent heat and light from the Sun from shining on walls. This prevents heat from being transferred to the walls, and then to the air inside.

Energy ratings

Most modern appliances such as air conditioners, heaters and televisions have an energy star rating. These ratings are shown on a label and indicate the amount of energy consumed with average use. The star rating indicates the efficiency of the appliance and is determined by the amount of energy used and the size of the appliance. A large television will be less efficient than a small television.

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

8.3 Check your learning

Comprehend

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

2 **Represent** the fire drill method used by First Nations peoples as a Sankey diagram (with an input energy of 16 J, kinetic energy of 10 J, thermal energy of 6 J).

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

  a heating during winter b cooling during summer.

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

Apply

5 a A hair dryer transforms electrical energy into thermal energy. **Describe** how the hair dryer generates thermal energy.

  b **Predict** what would happen if the hair dryer used materials that were good conductors.

6 The temperature inside and outside a house was measured over 24 hours and displayed in Figure 4. **Determine** from the graph whether the house was insulated. **Justify** your answer (by using numbers from the graph as evidence).

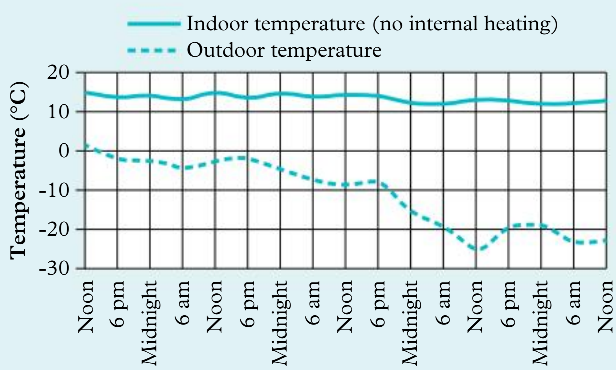


Figure 4 A graph showing the temperature inside and outside a house

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

8.4 Athletes need to be energy efficient

Learning intentions

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

- identify the energy transfers and transformations involved in archery and pole vaulting
- explain how becoming more energy efficient can improve performance in a sport.

Key ideas

- Archery involves energy being transferred from the archer to the string, to the kinetic energy of an arrow.
- Pole vaulting involves energy being transferred into and out of an elastic pole.

Efficiency in sport

An understanding of energy efficiency can improve our understanding of the world around us. From reducing the amount of energy lost in archery, to increasing the energy efficiency of the poles used in pole vaulting, understanding how to reduce waste energy can improve athletic performance.

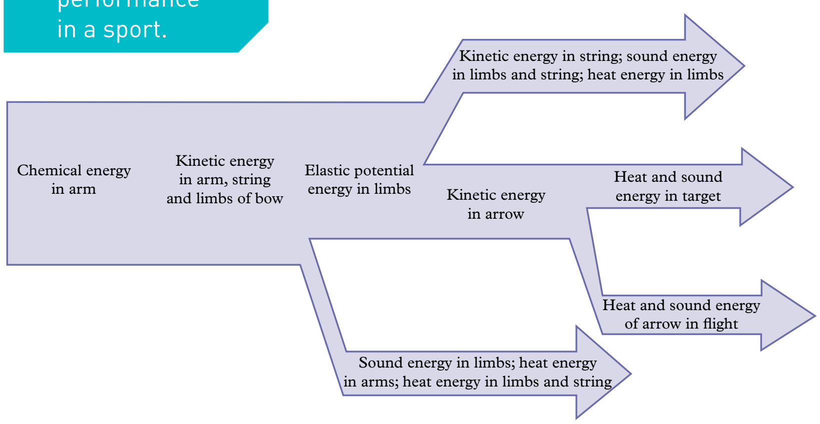


Figure 1 A Sankey diagram of energy transfer and transformation in archery

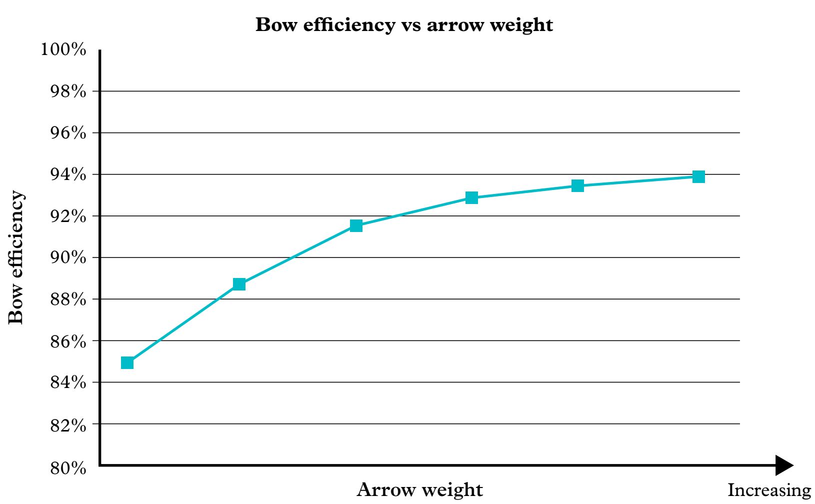


Figure 2 As the arrow weight increases, the bow becomes more efficient.

Archery

Archery is a sport that involves using a bow to shoot an arrow at a target. There are three places for energy transfer to occur in the shooting of an arrow. The first energy transformations involve the chemical energy in the archer's arm being transferred to kinetic energy as the fingers pull back the string on the bow. The kinetic energy is immediately transferred to elastic potential energy in the stretched string. For this to be efficient, the string must be evenly stretched. Waste energy is generated as heat in the arm and the string. When the fingers let go of the stretched string, the elastic potential energy is transferred and transformed into kinetic energy in the arrow. This process produces heat and sound from the string bouncing back to its original position and heat and sound from the friction of the arrow moving through the air (Figure 1).

Studies of energy efficiency in archery have found that as the weight of the arrow increases, the bow becomes more efficient (Figure 2). This means less heat and sound is produced when the archer shoots a heavier arrow.

Pole vaulting

Pole vaulting is a unique sport that requires the athlete to have a solid understanding of energy efficiency. Many observers of the sport make the mistake of thinking that the vaulting athlete needs to have strong upper body strength to 'pull' themselves over the bar. Although athletes in this sport do require arm strength to carry the pole and leg strength to increase kinetic energy in the run up, the key to being a good pole vaulter is to understand the importance of efficient energy transfer and transformation in the pole.

In the run-up, the athlete needs to rapidly increase their speed. This generates kinetic energy (from the chemical energy in their bodies). At the end of the run, the athlete plants their pole at the base of the bar. The kinetic energy of the run-up is transferred into the pole, causing it to bend and store energy as elastic potential energy. Like most energy transfers, waste heat energy is generated. The elastic energy is released as the pole straightens, transferring back to the athlete, and transforming into gravitational potential energy as the athlete rises into the air. As the athlete reaches full height (peak gravitational energy), the athlete lets go of the pole and moves over the bar and falls to the mat below. The athlete able to jump the highest bar without knocking it off will win the competition. This process is shown in Figures 3 and 4.

The pole is the main point of energy transfer and transformation. The efficiency of energy transfer from the athlete to the pole, and from the pole back to the athlete, is the key to a successful jump. Early poles were made of wood with elastic properties. In the 1850s, wood from ash or hickory trees was used for the poles. Seven years later, athletes started using bamboo poles because they were able to store more elastic energy. In the 1940s, steel poles were trialled before flexible fibreglass was used. Most modern pole vaulters have added carbon fibre to the fibreglass to increase the flexibility and a fast recoil. This transfers more of the elastic energy stored in the pole to the vaulter.

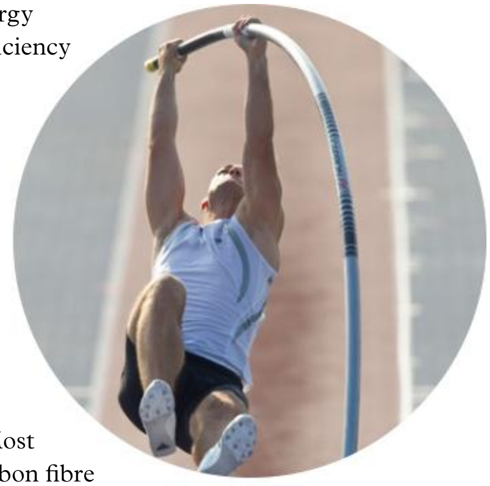


Figure 3 Pole vaulting involves an athlete using a pole to jump 5–6 m over a bar.

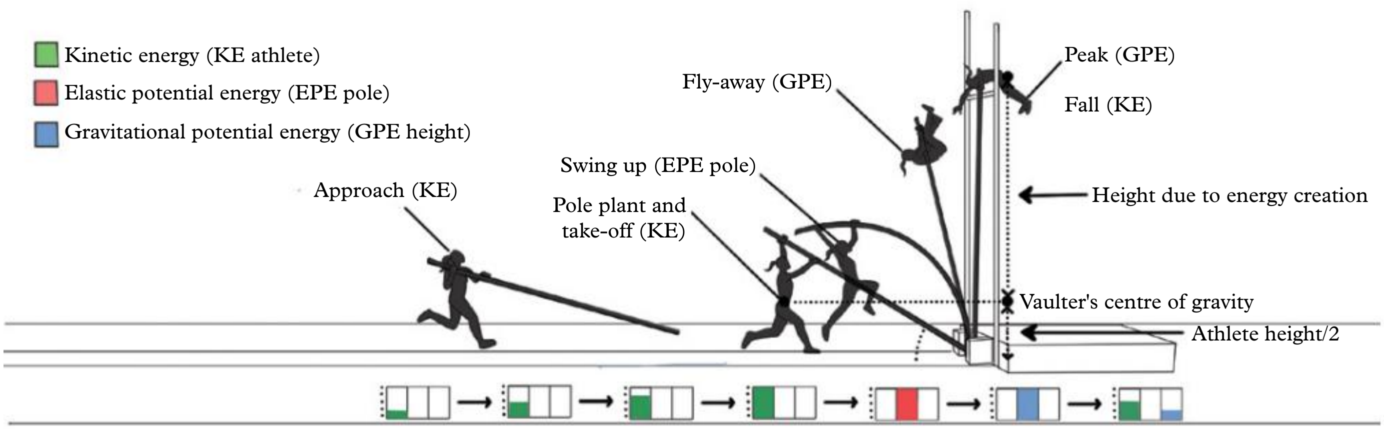


Figure 4 Pole vaulting involves the transfer of energy in and out of the pole.

8.4 Check your learning

Retrieve

1 **Identify** two types of energy involved in archery.

Comprehend

2 **Draw** flow diagrams for the energy transformation process that occurs in:

  a archery

  b pole vaulting.

3 **Represent** the energy transfer in pole vaulting with a Sankey diagram.

Apply

4 **Propose** why a moving arrow would generate thermal heat energy.

5 There are two types of bows that are used in competition archery in the Paralympic events. The recurve bow has limbs that curve away from the archer. The compound bow is less flexible and uses pullies and cables to store the elastic potential energy. Both bows are effective in shooting arrows, but the recurve bow produces more sound when the arrow is released. Use this description to **identify** which bow is more efficient. **Justify** your decision.

Quiz me

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

CHAPTER 8 REVIEW

ENERGY EFFICIENCY

Retrieve

1 **Identify** the equation used to calculate energy efficiency.

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

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

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

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

2 **Identify** the amount of thermal energy produced by the electric motor in Figure 1.

A 14 J

B 36 J

C 50 J

D 86 J

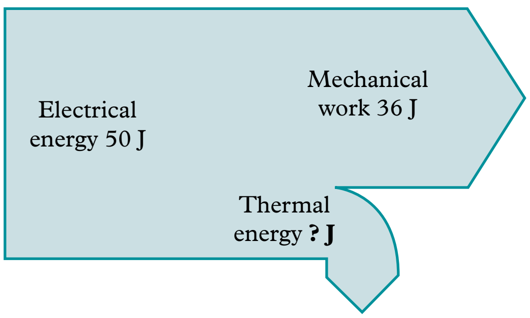


Figure 1 Sankey diagram showing energy produced by an electric motor

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

A It captures light energy to power the house.

B It stops heat getting in through the windows.

C It deflects light energy away from the house.

D It helps to keep heat out of the house during the day.

4 **Recall** what the stars on the energy rating of an appliance represent.

Comprehend

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

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

7 **Explain** why a ball that rebounds high is considered more efficient than a ball that does not rebound at all.

8 **Explain** what is meant by 'waste energy'.

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

Analyse

10 **Classify** the following as either true or false. Rewrite any false statements to make them true.

a Archery bows only hold stored energy when they are stretched.

b When an object is thrown up in the air, it gains gravitational potential energy.

c Thermal energy is a type of potential energy.

d Energy can be transferred with 100% efficiency.

11 **Analyse** each of the following situations and **identify** the main form of energy in each.

a a ground oven used for cooking

b a stretched archery bow

c the Sun heating the walls of a house

d an arrow flying through the air

12 For each of following, **consider** the energy transformation and **identify** a device that performs that transformation.

a electrical energy into light energy

b elastic energy into kinetic energy

c electrical energy into sound energy

d gravitational energy into electrical energy

e kinetic energy into electrical energy

13 **Compare** the energy efficiency of a bamboo pole vault and a carbon fibre/fibreglass pole vault.

14 **Compare** the effectiveness of a veranda and window awnings in increasing the energy efficiency of an uninsulated house in summer.

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

i 20 units of input energy into 12 units of useful output energy

ii 600 units of input energy into 500 units of useful output energy.

b For i and ii from part a, **explain** what happened to the other energy (i.e. 8 units in i and 100 units in ii).

16 A large wind turbine is able to transform 2500J of mechanical energy into 2000J of electrical energy each second.

a **Calculate** the amount of thermal waste energy produced each second.

b **Calculate** the efficiency of the wind turbine.

17 Figure 2 illustrates the generation of electrical energy from coal. Use the Sankey diagram to **calculate** the energy efficiency of this process.

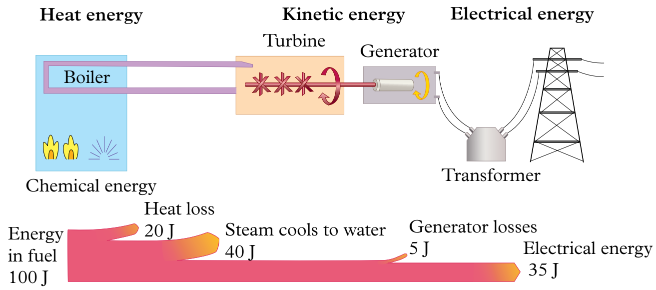


Figure 2 Generation of electrical energy

18 **Identify** which of the three lights in Figure 3 is most energy efficient. Use calculations.

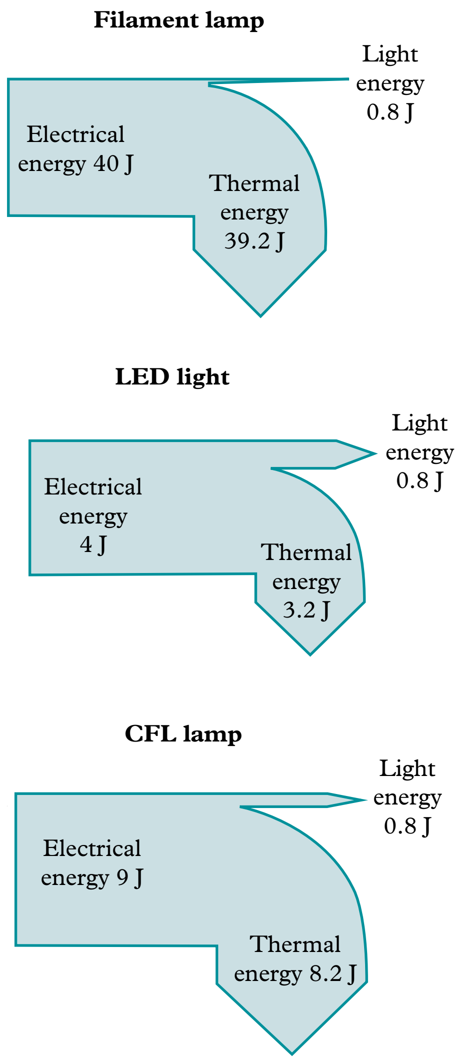


Figure 3 Sankey diagrams showing energy efficiency of three lights

Apply

Critical and creative thinking

19 **Evaluate** the energy efficiency of the light globes in Figure 4 (by calculating the efficiency of the light being produced, comparing the amount of waste energy produced and deciding which type of globe you would recommend in your house).

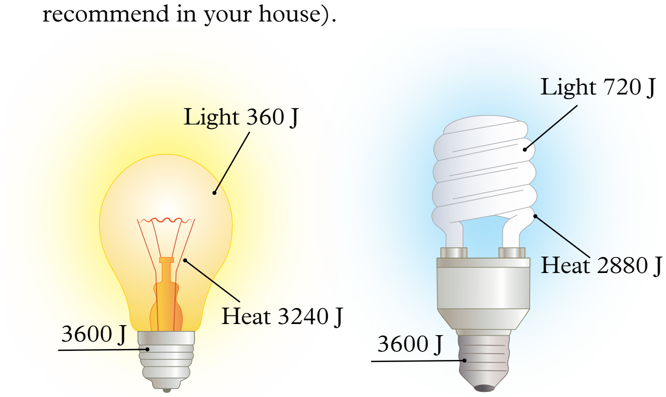


Figure 4 Energy efficiency of two light globes

20 **Evaluate** the efficiency of a ground oven (by describing how a ground oven cooks food, describing the advantages and disadvantages of a ground oven, comparing a ground oven to the oven in your kitchen, describing when using a ground oven would be more efficient than a kitchen oven).

21 **Determine** the main source of electrical energy generation in your area. Describe how that energy is generated.

22 The perpetual motion machine is a hypothetical machine that could keep working forever without any energy source. Use the law of conservation of energy to **discuss** why this machine would be impossible.

Social and ethical thinking

23 A mobile phone charger that is switched on at the power point is constantly using energy, even when no phone is placed on it to be charged. **Evaluate** the ethics of maintaining this energy use when your phone is fully charged (by describing the advantages and disadvantages of leaving the phone charger on, deciding whether you are using an 'ends justify the means' consequentialism approach or a 'rules-based' deontology approach, and deciding whether the phone charger should be left on).

Research

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

» Energy-efficient transportation

Many forms of transport currently rely on the production and use of fossil fuels. A vehicle that is not energy efficient will need to use more fossil fuel to travel than an energy-efficient vehicle.

- » Identify the types of waste energy that would be produced in travel.
- » Describe how this waste energy is generated.
- » Explain how the amount of waste energy can be minimised in the design of energy-efficient vehicles.

Figure 5 Electric cars use less energy than conventional cars.

» Electricity generation

Each time energy is transferred or transformed, waste energy is produced.

- » Describe two ways electrical energy is generated (nuclear, hydroelectrical, gas, solar and wind).
- » For each process, compare the waste energy that is generated each time the energy is transferred and transformed.
- » Use the comparison to identify and justify which process of electricity generation is most efficient.

» Energy-efficient housing

In previous societies, energy efficiency was important because people had limited access to different types of energy supply and their applications compared to today.

- » Research how civilisations in tropical areas designed their homes to keep them cool and damp free.
- » Describe three types of energy-efficient practices that humans have used through the ages.
- » Identify what is meant by a 'passive house'.

Figure 6 Solar panels on houses improve energy efficiency.

Chapter checklist

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

	I can do this.	I cannot do this yet.
• Explain the law of conservation of energy. • Describe the relationship between waste energy and the energy efficiency of a device. • Use the efficiency formula to calculate unknown values.	☐	☐ Go back to Topic 8.1 'Energy cannot be created or destroyed'. Page 164
• Use Sankey diagrams to show energy inputs, changes and outputs. • Interpret Sankey diagrams.	☐	☐ Go back to Topic 8.2 'Sankey diagrams can represent energy efficiency'. Page 166
• Describe examples of energy-efficient practices used by First Nations peoples. • Describe examples of features in buildings that improve energy efficiency.	☐	☐ Go back to Topic 8.3 'Energy efficiency can reduce energy consumption'. Page 168
• Identify the energy transfers and transformations involved in archery and pole vaulting. • Explain how becoming more energy efficient can improve performance in a sport.	☐	☐ Go back to Topic 8.4 'Athletes need to be energy efficient'. Page 170

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Quizlet
Play a Quizlet game to test your knowledge.

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

CHAPTER

9

EXPERIMENTS

SCIENCE LAB RULES

Being safe in the lab is essential to prevent you and others from getting hurt.
Whenever you are in the lab, you must always follow the rules below.

DO:

- » wear a lab coat for practical work
- » keep your workbooks and paper away from heating equipment, chemicals and flames
- » tie long hair back whenever you do an experiment
- » wear safety glasses while mixing or heating substances
- » tell your teacher immediately if you cut or burn yourself
- » tell your teacher immediately if you break any glassware or spill chemicals
- » wash your hands after any experiments
- » listen to and follow the teacher's instructions
- » wear gloves when your teacher instructs you to.

DON'T:

- » run in a laboratory
- » push others or behave roughly in a laboratory
- » eat in a laboratory
- » drink from glassware or laboratory taps
- » look down into a container or point it at a neighbour when heating or mixing chemicals
- » smell gases or mixtures of chemicals directly; instead, waft them near your nose and only when instructed
- » mix chemicals at random
- » put matches, paper or other substances down the sink
- » carry large bottles by the neck
- » enter a preparation room without your teacher's permission.

1.1 What if the absorbency of different paper towels was compared?

EXPERIMENT

Aim

To measure and compare the absorbency of different brands of paper towel, which vary in their cost per square centimetre.

Materials

- 5 different brands of paper towel (one must be a home brand)
- Small beaker of water with a dropper
- 250 mL beaker
- 100 mL measuring cylinder
- Scissors
- Ruler and pencil
- Calculator
- Stopwatch

Method

1. Cut a 20 cm × 20 cm square from one sheet of each brand of paper towel.
2. Record the brand, price, number of sheets and the dimensions of each sheet in centimetres.
3. Fill the measuring cylinder with water to the 100 mL mark, using the dropper for the last 2–3 mL. Ensure that your eyes are level with the scale, to avoid parallax error.
4. Immerse the square of paper towel in water for 10 seconds. Use the stopwatch for timing. Hold the paper towel above the measuring cylinder, without squeezing the towel, for another 10 seconds, then remove it and place it in the large beaker.
5. Record the level of water left in the measuring cylinder and, hence, the volume of water absorbed by the paper towel in 10 seconds.
6. Repeat steps 1–5 for two other sheets of the same brand of paper towel.

Inquiry

What if the absorbency of more expensive paper towels was compared to home brand paper towels?

Answer the following questions with regard to your inquiry question.

- Identify the brands of paper towel that you will test.
- Write a hypothesis (If … then … because …) for your inquiry.
- Identify the (independent) variable that you will change from the first method.
- Identify the (dependent) variable that you will measure and/or observe.
- Identify two variables that you will need to control to ensure a valid test. Describe how you will control these variables.
- Identify the materials you will need for your experiment.
- In your logbook, write down the method you will use to complete your investigation.
- Draw a table to record your results.
- Show your teacher your planning for approval before starting your experiment.

Results

- Calculate the total surface area and the cost per square centimetre for each paper towel, and record your results in the table.
- The total surface area of the paper towel roll is calculated as follows:

$$A = l \times w \times \text{number of sheets of paper towel}$$

- The cost of paper towel per square centimetre is calculated as follows:

$$\text{Cost of paper towel} = \frac{\text{cost of roll}}{\text{total area of roll}}$$

- Calculate the average volume of water absorbed per 20 cm square and record your results in the table.
- The average volume of water absorbed per 20 cm square is calculated as follows:

$$\text{Average volume of water} = \frac{\text{volume 1} + \text{volume 2} + \text{volume 3}}{3}$$

- Draw a bar graph to show the average volume of water absorbed for each brand.
- In your graph, place the brands in order from least expensive to most expensive. On each bar, state the price per square centimetre of that brand.

Discussion

1. State the reasons for the following.
   a. Three readings were taken each time and then averaged.
   b. The same-sized square was used each time.
   c. The cost of the paper towel per square centimetre was calculated and used instead of the total cost of the roll.
   d. Each square of paper towel was allowed to drip for precisely 10 seconds before removing it from the water.
2. Compare the absorbency of the different brands to the predictions you made in your hypothesis.
3. Evaluate the validity (by identifying any variables that might not have been controlled) and reliability (by describing whether you or other scientists will achieve the same results) of this experiment.
4. Identify the limitations of these results (by describing how testing with other solutions may achieve different absorbency).

Conclusion

From your graph, identify any apparent relationship between the cost of the paper towel per square centimetre and its absorbency. Provide evidence (by mentioning values) from your results to support your answer.

2.1 Testing your senses

CHALLENGE

Aim

To determine how skin temperature and touch sensors respond to stimuli.

PART A: TEMPERATURE RECEPTORS

What you need:

Very warm water, room temperature water, warm water (no hotter than 50°C; use the thermometer to check), ice cubes, 3 ice cream containers, thermometer, timer

What to do:

1 Half-fill one container with cold water and add the ice cubes.
2 Half-fill the second container with room temperature water.
3 Half-fill the last container with very warm water.
4 Place one hand in the iced water and the other in the very warm water for 2 minutes.
5 Remove your hands from the iced and very warm water and place them (at the same time) in the room temperature water.

Questions

1 Identify the stimulus experienced by the hand in very warm water.
2 Contrast the information provided by the temperature sensors in the hand when it moved from:
   a the iced water to the room temperature water
   b the very warm water to the room temperature water.
3 Evaluate the effectiveness of the temperature receptors on the skin of your hand (by comparing the messages sent to the brain by both hands and deciding whether the temperature receptors provide an accurate measure of the water temperature).
4 Explain why scientists use a thermometer rather than their hands to test the temperature of solutions.

PART B: TOUCH RECEPTORS

What you need:

2 toothpicks, ruler, modelling clay, blindfold

What to do:

1 Work in pairs. One person puts on the blindfold.
2 Place the toothpicks 50 mm apart in the modelling clay.
3 Pick up the modelling clay and place the pointed ends of the toothpicks gently on the blindfolded person's finger. Ask them whether they feel one or two points.
4 If two points are felt, move the toothpicks closer together and repeat step 3.
5 Repeat steps 3 and 4 until the blindfolded person reports 'one point' for the first time.
6 Record the distance between the two pointed ends of the toothpicks in a table.
7 Repeat this procedure for the palm of the hand, back of the hand and forearm.

Questions

1 Contrast the 'two point' distances on different areas of the skin.
2 Identify the part of the body that was able to detect the closest toothpicks.
3 Identify which skin areas have the most touch receptors. Justify your answer (by describing how touch receptors work, describing how a receptor might mistake two toothpick points for a single touch, and using your answers to questions 1 and 2 to decide which area of skin has the most touch receptors).

2.2 Pipe cleaner neurons

CHALLENGE

Aim

To model a neuron.

What you need:

5 different-coloured pipe cleaners representing different parts of the neuron (cell body, axon, dendrites, myelin sheath, synaptic terminal), A3 or A4 paper, sticky tape, red felt-tipped pen

What to do:

1 Roll a pipe cleaner into a ball to represent the cell body.
2 Attach another pipe cleaner to the cell body by pushing it through the ball so that there are two halves sticking out. Twist the two halves together into a single long axon.
3 Push another pipe cleaner through the cell body on the side opposite the axon to make a dendrite. This can be shorter than the axon, and you can twist more pipe cleaners to make more dendrites.
4 Wrap a pipe cleaner along the length of the axon to form the myelin sheath.
5 Wrap another pipe cleaner on the end of the axon to make the synaptic terminal.
6 Tape your finished pipe cleaner neuron onto a piece of A3 or A4 paper and label the parts.
7 Mark the path of the nerve impulse, from start to finish, along the neuron.

Questions

1 Describe the role of a neuron.
2 Describe the role of the myelin sheath.
3 Explain how the message moves from one neuron to another via the synapse.

Figure 1 Use pipe cleaners to model a neuron.

2.3A Testing reflexes

CHALLENGE

Aim

To test the pupil reflex.

What to do:

1 Look at the pupils (the black spots in the middle of the eyes) in the eyes of a classmate. Note the size of the pupils.

2 As a class, dim the lights in the room. After a few minutes, look at your classmate's eyes and note the size of the pupils.
   > How big are the pupils?

3 Turn the lights back on. Check the size of your classmate's pupils again.
   > How big are the pupils this time?

Questions

1 Describe how the pupils of the eyes changed when:
   a the room was dimmed
   b the lights were turned back on.

2 Describe the role of the pupil in the eye.

3 Describe an advantage of the change in pupil size when moving in and out of dark space.

4 With a partner, design an experiment to test another reflex. Write an aim and a reproducible method for your experiment.

Figure 1 Which pupil is in low light and which is in bright light?

2.3B How fast is the nervous system?

CHALLENGE

Aim

To compare the response time of different sensors.

What you need:

Metre ruler, blindfold

What to do:

1 Work in pairs. Student 1 holds the ruler between their thumb and forefinger so that the ruler hangs with the zero mark at the bottom. Student 2 waits with their thumb and forefinger at the bottom of the ruler, level with the zero mark.
2 Student 1 drops the ruler without warning. Student 2 catches the ruler as fast as they can between their thumb and forefinger.
3 Record the number of centimetres the ruler has dropped, by looking at the location of Student 2's thumb and forefinger on the ruler (Figure 1a).
4 Repeat until you have 10 results for each student.
5 Work out the average reaction distance for each student.
6 Measure the approximate distance the messages must have travelled if they travelled from your eye to your brain to your fingers.
7 Try the experiment using touch only. Blindfold Student 2. When Student 1 drops the ruler, they tap Student 2 on the head. Does this make a difference to the reaction distance?
8 Try the experiment using hearing only. Blindfold Student 2 (Figure 1b). When Student 1 drops the ruler, they say 'now'. Does this make a difference to the reaction distance?

Questions

1 Contrast the results of the three experiments (no blindfold, blindfold and tap, blindfold and voice) to determine which experiment had the fastest results.
2 Evaluate the reliability of your results (by describing whether all the variables were controlled, explaining possible errors that need to be improved, and deciding whether anyone who repeated the experiment would obtain the same results).

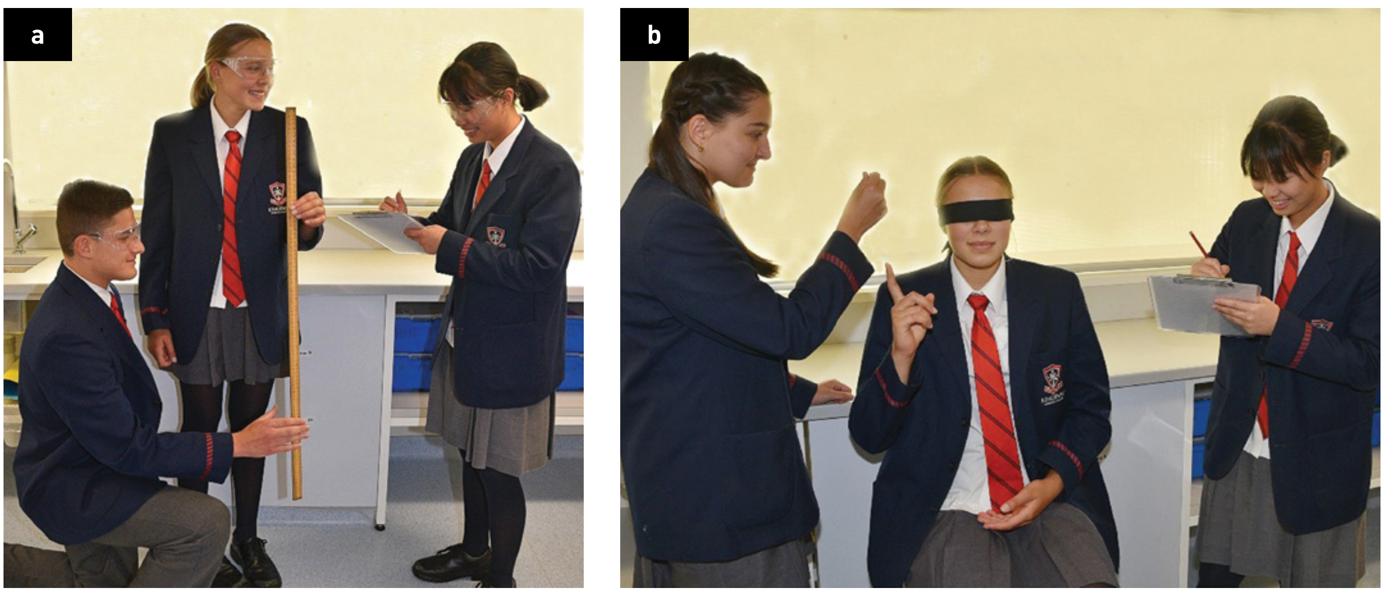

Figure 1 Testing responses **a** using sight **b** using hearing

2.4 Sheep brain dissection

SKILLS LAB

CAUTION! Wear your lab coat, safety glasses and plastic gloves. Be careful with the scalpel because it is likely to be very sharp. Cut away from your hands and other people.

Aim

To explore the structure of a sheep's brain.

What you need:

Sheep's brain, dissecting board, scalpel, dissecting scissors, coloured pins, microscope, slide, cover slip (optional), forceps

What to do:

1 Examine the outside of the brain. Set the brain down so that the flatter side, with the white spinal cord at one end, rests on the board (Figure 1). Using the different-coloured pins, identify the two hemispheres, the four lobes of the brain, the spinal cord, the cerebellum and the cerebrum. Draw a diagram (in pencil) or take a photo that displays the different sections of the brain. Check this with your teacher before continuing.

Figure 1 Step 1

2 Remove the pins and turn the brain over (Figure 2). Identify the medulla and the pons. Draw a diagram or take a photo that displays these parts of the brain.

Figure 2 Step 2

3 Place the brain with the curved top side of the cerebrum facing up. Use a scalpel to slice through the brain along the centre line, starting at the cerebrum and going down through the cerebellum, spinal cord, medulla and pons (Figure 3). Separate the two hemispheres of the brain (Figure 4). Draw a diagram or take a photo that displays these parts of the brain.

Figure 3 Step 3: slice along the brain.

Figure 4 Step 3: separate the two hemispheres.

4 Cut one of the hemispheres in half lengthwise. Record what you see.

5 If a microscope is available, slice a very thin section of the cerebrum and put it on a slide, covering it with a drop of water and a cover slip. Draw a diagram of what you observe at low and high magnifications. Follow the same procedure with a section of the cerebellum, and then compare the two sections of the brain.

Questions

1 Describe the texture of the brain (smooth, rough, slippery, waxy, tacky, flimsy, chalky, hard, soft, granular, rubbery).

2 Compare the structure of the sheep's brain and what you know about a human brain.

3 Contrast the cognitive functions (ability to think and reason) of a sheep and a human. Describe how these differences could be reflected in the structure of the brain.

2.6 Glands and organs of the endocrine system

CHALLENGE

Aim

To identify the path of a hormone from its gland to the target organ.

What you need:

Large sheet of butcher's paper, felt-tipped pen, sticky tape

What to do:

1 Working in pairs, draw an outline of your partner's body on the paper.
2 With your partner, draw in the glands and organs of the endocrine system. Using the information in Table 1 (page 36), annotate each gland with a brief description, in your own words, of what it is responsible for.
3 Use colour coding and arrows to show the path of the hormone(s) produced by each gland to its target organ.

Questions

Choose one gland or organ to research.

1 Identify the main hormone the gland secretes.
2 Describe how the hormone affects the target cells in the target organ.
3 Describe one disorder that results from a malfunction of this organ or gland.

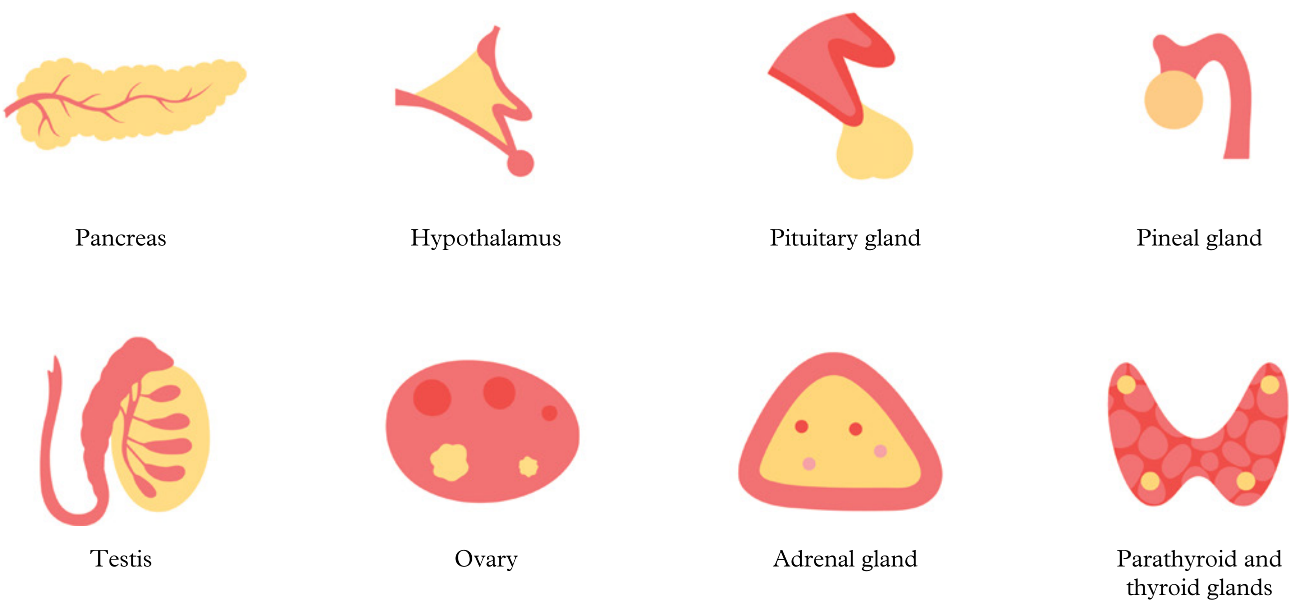

Figure 1 The organs of the endocrine system

2.7 Experiencing homeostasis

EXPERIMENT

Aim

To demonstrate how homeostasis maintains control of the heart rate during and after exercise.

Materials

- Stopwatch
- Heart rate monitor (optional)

Method

1 While sitting down, find your pulse and count the number of times your heart beats in 15 seconds.
2 Multiply this number by 4 to determine the number of beats every minute.
3 Measure your respiration rate by counting the number of breaths you take in 1 minute.
4 Do repeated step-ups or star jumps for 2 minutes. (Make sure you are wearing appropriate shoes.)
5 Measure your heart rate and respiration rate immediately after stopping exercise.
6 Measure your heart and respiration rate every 2 minutes for 10 minutes.

Results

1 Record the data in a table.
2 Draw a line graph showing how your heart rate varied after exercise.
3 Draw a line graph showing how your respiration rate varied after exercise.

Discussion

1 Describe how your breathing rate changed during and in the 10 minutes after exercise.
2 Explain why your heart rate increased during exercise.
3 Describe what happened to your heart rate during the 10 minutes after exercise.
4 Use the concept of homeostasis to explain why your heart rate was different before, during and after exercise.

Conclusion

Describe how homeostasis ensures that our muscles get enough nutrients and remove wastes during exercise.

Figure 1 Heart rate monitor on a smart watch

2.10A Investigating pathogens

CHALLENGE

Pathogens are organisms that cause disease.

Aim

To investigate a disease-causing pathogen.

What you need:

A selection of research resources, such as books, medical dictionaries, journals and computers

What to do:

1 Working in small teams, brainstorm for 3 minutes and prepare a list of as many pathogen-caused diseases as you can.

2 You now have 2 minutes to predict the type of organism that causes each of the diseases in your list. Next to each disease, write one of the following words as your prediction: worm, fungus, protozoan, bacterium, virus.

3 Spend a minute discussing how your team can use your resources to confirm or refute your prediction. You must use at least two different types of valid reliable resources.

4 You now have 10 minutes to research the list of diseases to confirm which group of organisms causes each disease.

Questions

1 Describe the types of resources that you used in your research. Describe two types of resources that you avoided and why you avoided them.

2 Draw a bar graph showing the number of diseases you listed for each type of organism.

3 Identify the organism that occurred most frequently (the mode) on your list. Describe why you might be more familiar with the causes of some types of disease.

Figure 1 Journals can be used to conduct research on disease.

2.10B Investigating germ theory

EXPERIMENT

CAUTION! Do not open the tape seals.

Aim

To determine what factors affect the growth of airborne microbes.

Materials

- Agar plates
- Various disinfectants
- Incubator
- Sticky tape or paraffin film
- Permanent marker
- Timer

Method

1. Open the lid of one agar plate and leave it sitting on the bench for 15 minutes.
2. Place the lid on the top and seal the agar plate with sticky tape. Write the label 'Open bench' around the edges underneath the plate, so that it does not obstruct the view of the agar.
3. Leave another agar plate unopened. Seal it with sticky tape. Label the plate 'Control'.
4. Incubate the agar plates at 35–37°C for approximately 3 days.
5. Do not open the plates! Examine the closed plates for any growth.

Inquiry

What if the first agar plate was sprayed with a disinfectant before being incubated?

Answer the following questions with regard to your inquiry question.

- Write a hypothesis (If … then … because …) for your inquiry.
- Identify the (independent) variable that you will change from the first method.
- Identify the (dependent) variable that you will measure and/or observe.
- Identify two variables you will need to control to ensure a valid test. Describe how you will control these variables.
- Identify the materials you will need for your experiment.
- In your logbook, write down the method you will use to complete your investigation.
- Draw up a table to record your results.
- Show your teacher your planning for approval before starting your experiment.

Results

Record all your results. You could take photos showing the microbe growth on the agar plates.

Discussion

1. Define the term 'bacterial colony'.
2. Describe how a bacterial colony forms on an agar plate.
3. Explain why colonies are different colours and sizes.
4. Compare the colour and size (diameter) of the different colonies that grew on each plate.
5. Explain why you left one agar plate unopened.
6. Evaluate whether your results support germ theory (by explaining germ theory, comparing your results to germ theory, and deciding whether your results support germ theory).
7. Evaluate whether your results support your hypothesis (by describing your results in 1–2 sentences, comparing your results to your hypothesis, and deciding whether your hypothesis was supported).

Conclusion

Describe the factors that affect the growth of microbes.

2.11 Modelling infection and vaccination

CHALLENGE

Aim

To model how a disease can spread in a group.

What you need:

1 M sodium hydroxide, 0.1 M hydrochloric acid, water, phenolphthalein indicator, plastic cups, pipette, felt-tipped pen

What to do:

1 Half-fill a plastic cup with water and label it with your name.
2 All students place their cups on one table.
3 Students turn their back while the teacher adds 2 mL of sodium hydroxide to one cup. This represents a student having an infection.
4 Students then collect their cups and use the pipettes to exchange 3 mL of water with three other students. This is equivalent to shaking hands. Record who you 'shook hands' with in a table like the one below.

Person 1	Person 2	Person 3

5 Add a few drops of phenolphthalein indicator to each cup, to determine who caught the disease.
6 Use the information recorded in the table to determine who the original source of the infection was.
7 Repeat steps 1–5, this time choosing whether or not to become 'vaccinated'. Vaccination is done by adding 2 mL of hydrochloric acid to your cup of water. Redraw the table to record who you shook hands with after some people were vaccinated.
8 Repeat this activity, increasing the number of people vaccinated.

Questions

1 Identify the number of people who became infected when no one had been vaccinated.
2 Identify the number of people who became infected when a few people had been vaccinated.
3 Identify the number of people who became infected when more people had been vaccinated.
4 Explain why vaccination affected the number of people who became infected.
5 Describe a real-life example of how vaccination can protect vulnerable members of the community.

3.1 Vegetative propagation

EXPERIMENT

Aim

To produce a new plant using vegetative propagation.

Materials

- 2 × 500 mL beakers
- Distilled water
- Scissors
- Geranium plant
- Flowerpots with potting mix

Method

1 Fill the beakers 3/4 full with distilled water.
2 Use the scissors to cut four healthy stems with 1–2 healthy leaves on each from the same plant.
3 Place the cut ends of the stems into the distilled water.
4 Observe the cut ends of the stems for 2–3 weeks.
5 Transfer the cuttings to the flowerpots.
6 Water the plants regularly and observe their growth.

Results

Record your observations in a logbook. Take photos of any changes in growth.

Discussion

1 Identify this form of reproduction as sexual or asexual. Use evidence from your experiment to justify your answer.
2 Compare the genetic material in the parent plant to that of the new (daughter) plants.
3 Identify if the parent and daughter plants will be identical in shape and size. Justify your answer by describing the factors that affect plant growth.
4 A student claimed that they were making plant clones. Define the term 'clones'. Use your definition to evaluate if the student's claim is correct.

Conclusion

Describe what you know about vegetative propagation.

3.5 Working with the RSPCA

CHALLENGE

The RSPCA is a community-based charity, well known in Australia for its work with and for animals. Unlike humans, animals do not have a voice and so they cannot ask for help. The RSPCA is one of the best 'voices' for animals and their rights. One of the RSPCA's biggest campaigns focuses on the importance of desexing pets, particuarly cats. Every year, approximately 60 000 cats are brought in to the RSPCA; of these, over half have to be put down.

Aim

To create a mathematical model (or diagram) demonstrating how many cats can be produced from two fertile cats.

What to do:

The growth modelled in this task is exponential, meaning that when the two cats reach 6 months of age they can start to breed and, after 60 days, will have a litter of four kittens, after 6 months these four kittens will also be able to have kittens themselves and so on.

Cats can start the breeding cycle almost straight after having kittens, which means, on average, cats can have three litters of kittens a year.

Include a graph that shows the growth of numbers of cats against time.

Questions

1 Explain what desexing is and why it is important.

2 Based on your calculations, identify how many cats were produced after 4 years.

3 Describe how desexing the first mating pair would change your calculations.

4 Identify two other factors that could affect the number of cats in your calculations.

6 Explain why the RSPCA takes in so many more cats than dogs.

Figure 1 Desexing cats can have an impact on the number of unwanted kittens.

3.6 Flower dissection

EXPERIMENT

Aim

To examine the main parts of a flower.

Materials

- Newspaper
- A flower (you can dissect any type of flower available; lilies and fuchsias are a good choice)
- Scalpel blade or sharp knife
- Hand lens

Method

1. Place the newspaper on the bench.
2. Cut the flower off the stalk.
3. Observe the flower. Identify the main parts of the flower from Figure 1.
4. Draw a labelled diagram of the flower.
5. Gently remove the sepals and petals.
6. Look for the stamens with anthers at the top. The anthers hold the pollen. You should be able to dust some pollen onto your finger.
7. Cut off the male parts at the bottom of the petal.
8. Observe the female part of the flower. It has the stigma at the top and the ovary at the bottom.
9. Cut the ovary lengthwise. In it you will see tiny white scales, which are the ovules. When the ova inside the ovules are fertilised by the pollen, they will grow to become seeds and the ovary will grow to become the fruit.
10. Draw a labelled diagram of the ovary.
11. Clean up your bench by wrapping the flower in the newspaper. Wash your hands.

Results

Draw labelled diagrams of the male and female parts of the flower.

Discussion

1. Identify the colour of the filament (the stem of the stamen).
2. Describe how easy it was to clean the pollen from your fingers. Explain the advantage of a plant having sticky pollen.
3. Explain how the male and female parts were arranged to encourage pollination.
4. Identify if your flower is more likely to be self-pollinated or cross-pollinated. Justify your answer (using your observations to explain how the plant would be pollinated).
5. Identify if pollination is more likely to be by wind, water or animals. Justify your answer.

Conclusion

Explain what you know about the parts of a flower.

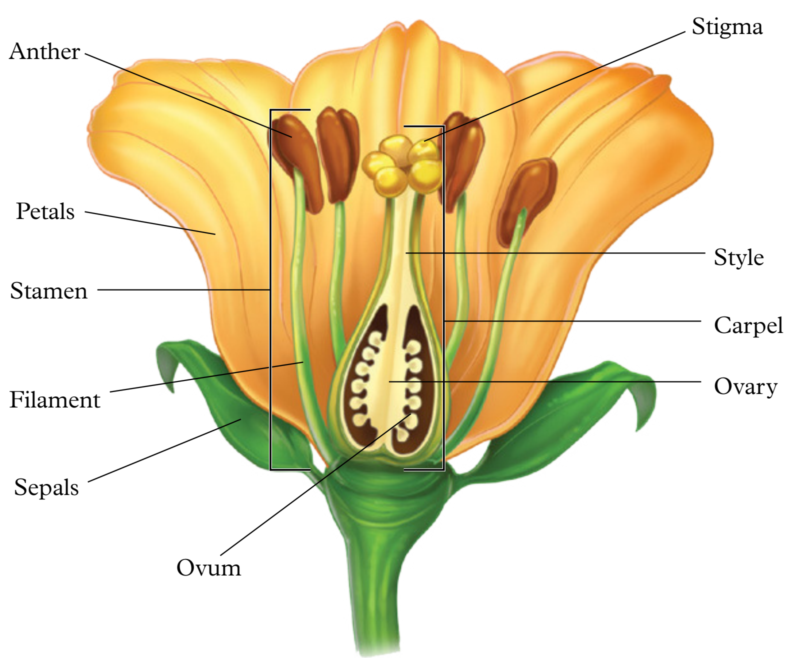

Figure 1 The structure of a flower

4.1A How can you tell what is inside?

CHALLENGE

This kind of investigation uses 'indirect evidence'. It has been used by many scientists when trying to work out what is inside the atom.

Aim

To use indirect evidence to generate a hypothesis.

What you need:

Ball, soft-drink can, 2 nails, wooden blocks, 3 small boxes, scales

What to do:

1. Form two teams (A and B) of three students to work with one another.
2. Team A places one item in each of the small boxes. The boxes are then closed.
3. Team B plans a way of determining what is inside each of the boxes without opening or touching them. They can use any equipment that is available in the science laboratory. The team writes the steps of the method in their logbooks.
4. Team B then follows the method to touch and examine the boxes, still without opening them.
5. Repeat the process, with Team B preparing a box and Team A determining what is inside the box.

Questions

1. Contrast 'direct evidence' and 'indirect evidence'.
2. Describe the senses that team B used to identify what was inside the box.
3. Describe how scientists might have used indirect evidence to model what is inside an atom.
4. Identify at least one other field of scientific investigation in which scientists would have to use indirect evidence to develop their theories.

Figure 1 How can you determine what is in the box?

4.1B Rutherford model of the atom

CHALLENGE

CAUTION! Do not eat the popcorn used in the experiment.

Aim

To model Rutherford's experiment that determined the structure of an atom.

What you need:

Hula hoop, string, empty matchbox, popcorn, scissors

What to do:

1 Tie the string securely around the matchbox and suspend it in the middle of the hula hoop.
2 One person holds the hula hoop so that it and the matchbox are hanging vertically, facing a second person.
3 The second person stands 1–2 m away and throws one piece of popcorn at a time at the hula hoop. Repeat 10 times.
4 Record how many kernels of popcorn go through the hoop and how many bounce off the matchbox.

Questions

1 The hula hoop represents a gold atom in Rutherford's experiment. Identify what the matchbox represents.
2 Identify the number of popcorn pieces that bounced off the matchbox.
3 Explain how your model of Rutherford's experiment provides supporting evidence for the Rutherford model of the atom.

Figure 1 What does popcorn represent in this experiment?

4.3 Calculating relative atomic mass

CHALLENGE

Your bag contains a sample of a new element called 'legumium' (symbol Lg). The atomic number of legumium is 4. There are three isotopes of this element. The smallest isotope is ^{4}Lg. The next in size is ^{5}Lg, which has an atomic mass of 5. The largest of the isotopes is ^{6}Lg, which has an atomic mass of 6. Your role is to determine the relative atomic mass of the element and its isotopes.

Aim

To model using the relative atomic mass of an element and its isotopes.

What you need:

1 bag of 'isotope sample' containing 8 large dried lima beans, 11 baby lima beans and 15 black-eyed peas, scales

What to do:

1 Record the total number of isotopes in your sample.
2 Record the number of each of the isotopes in your sample.
3 Weigh each legumium isotope and record the mass in an appropriate table.
4 Use the equation below to determine the relative atomic mass of legumium.

$$\text{Average atomic mass Lg} = \frac{(\text{number of } ^{4}\text{Lg} \times \text{mass } ^{4}\text{Lg}) + (\text{number of } ^{5}\text{Lg} \times \text{mass } ^{5}\text{Lg}) + (\text{number of } ^{6}\text{Lg} \times \text{mass } ^{6}\text{Lg})}{\text{total number of isotopes}}$$

Questions

1 For each legumium isotope, show its mass, atomic number and symbol.
2 Identify the number of protons, neutrons and electrons in each isotope.
3 According to your sample, explain which legumium isotope is most common in nature.

Figure 1 The dried lima bean isotope of legumium

4.4 Modelling radioactive decay

CHALLENGE

This activity illustrates the idea of exponential decay and half-life. Counters represent the nuclei.

Aim

To model the half-life of a radioactive compound.

What you need:

Counters (at least 30), A4 paper, disposable plastic cup, permanent marker

What to do:

1 Draw up a table like the one below, to record your results.

Number of shakes	Number of undecayed 'atoms'		
	Trial 1	Trial 2	Trial 3
0 (start)			
1			
2			
…			

2 Draw an M on one side of each counter.

3 Count the total number of counters that you have, record this number and place them in the plastic cup.

4 Shake the cup and tip all the counters onto the paper.

5 Those that have the 'M' facing upwards represent atoms that have decayed. Move these to a 'discard' pile.

6 Count the remaining 'nuclei' and record this number.

7 Place the remaining nuclei back into the cup, shake them and tip them out again.

8 Move the decayed nuclei to the discard pile and count those remaining. Record the number.

9 Continue until you have three or fewer nuclei.

10 Repeat the whole process two more times.

11 Draw a set of axes with the number of atoms remaining (vertical axis) and the number of shakes (horizontal axis). Plot points and draw a line of best fit through the points for each of the three trials.

Questions

1 The atomic nuclei were represented by counters. Describe how the half-life of the decay process was represented.

2 Contrast the shapes of the curves drawn for each trial.

3 Explain how the overall shape of the curves would or would not change if you started with more atomic nuclei.

4 In this experiment, you would eventually end up with no 'undecayed' counters. Evaluate whether this would be the case with a real radionuclide (by describing how atoms randomly decay in real life, comparing this to the counter demonstration and deciding whether every atom of a real radionuclide would become stable).

5.1 Comparing mass before and after a chemical reaction

EXPERIMENT

Aim

To determine if mass is conserved in a chemical reaction.

Materials

- Sodium bicarbonate
- Vinegar
- Balloon
- Balance
- Measuring cylinder
- 2 conical flasks
- Watch glass
- Spatula

PART A

Method

1. Copy the results table for Part A to record your results.
2. Weigh 2.0 g of sodium bicarbonate onto a watch glass.
3. Add 20 mL of vinegar to a flask.
4. Ensure the balance is reading zero. Weigh the vinegar and flask. Record this mass (M_1).
5. Predict whether the mass of the flask and vinegar after the reaction with the sodium bicarbonate will be more, the same or less than the initial mass.
6. Add 2 g of sodium bicarbonate (M_2) to the flask containing the vinegar and swirl until the bubbling stops.
7. Weigh the flask after the reaction has stopped. Record the final mass (M_3).

Results

Table 1 Results table

Mass of flask and vinegar (M_1)	Mass of sodium bicarbonate (M_2)	Total mass before reaction ($M_1 + M_2$)	Mass after reaction (M_3)

Figure 1 Sodium bicarbonate

PART B

Method

1 Copy the results table for Part B to record your results.
2 Weigh 2.0 g of sodium bicarbonate onto a watch glass.
3 Add 20 mL of vinegar to a flask.
4 Ensure the balance is reading zero. Weigh the vinegar, flask and a balloon. Record this mass (M_1).
5 Predict whether the mass of the flask, vinegar and balloon after the reaction with the sodium bicarbonate will be more, the same or less than the initial mass.
6 Add 2 g of sodium bicarbonate (M_2) to the balloon and carefully stretch the opening of the balloon over the neck of the flask so that the sodium bicarbonate does not spill.
7 Hold the end of the balloon directly over the top of the flask so that the sodium bicarbonate spills into the vinegar (keeping the contents sealed).
8 Weigh the flask, with the balloon still attached, after the reaction has stopped. Record the final mass (M_3).

Figure 2 Hold the end of the balloon directly over the top of the flask.

Results

Table 2 Results table

Mass of flask, vinegar and balloon (M_1)	Mass of sodium bicarbonate (M_2)	Total mass before reaction ($M_1 + M_2$)	Mass after reaction (M_3)

Discussion

1 Compare the initial and final masses for each part of the experiment.
2 Compare the results with your prediction.
3 Identify the gas that was produced.
4 Describe the purpose of sealing the flask with the balloon.
5 Describe the purpose of the control for this experiment.
6 Identify a possible error for this experiment. Describe how this error could be minimised.

Conclusion

Compare the results of this reaction to the law of conservation of mass.

5.2 Modelling chemical equations

CHALLENGE

Aim

To model the rearrangement of atoms in a chemical reaction.

What you need:

Paper bags, model atom kit (or laminated squares labelled oxygen (O-blue) atom, carbon (C-black) atom, hydrogen (H-white) atom), felt-tipped pen

PART A

What to do:

1 Each paper bag represents a molecule. Create a molecule of oxygen (O_2) by placing two oxygen 'atoms' in a paper bag. Write 'O_2' on the bag.

2 Use two paper bags and four model hydrogen atoms to create two molecules of hydrogen (H_2). You have now created the reactants in the chemical reaction:

$$2H_2 + O_2 \rightarrow 2H_2O$$

3 Label the two remaining paper bags 'H_2O'. Take the model atoms out of the reactant bags and place them in the product H_2O bags. Are there enough atoms to fill the H_2O bags?

Discussion

1 Explain why there needed to be more molecules/bags of hydrogen than oxygen.

2 Describe what would happen if one more molecule of oxygen was added to the reaction.

3 Compare this model reaction to the law of conservation of mass.

PART B

What to do:

1 Use new bags and the model atoms to create two molecules of methane (CH_4).

2 Identify the number of oxygen molecules (O_2) that you would need to turn these methane molecules into carbon dioxide (CO_2) and water (H_2O). Use the bags and model atoms to check your prediction.

Discussion

1 Identify the number of oxygen molecules you needed to balance this equation.

2 Identify the number of carbon dioxide and water molecules you were able to create with two methane molecules.

3 Write the word equation for this reaction.

4 Write the balanced chemical equation for this reaction.

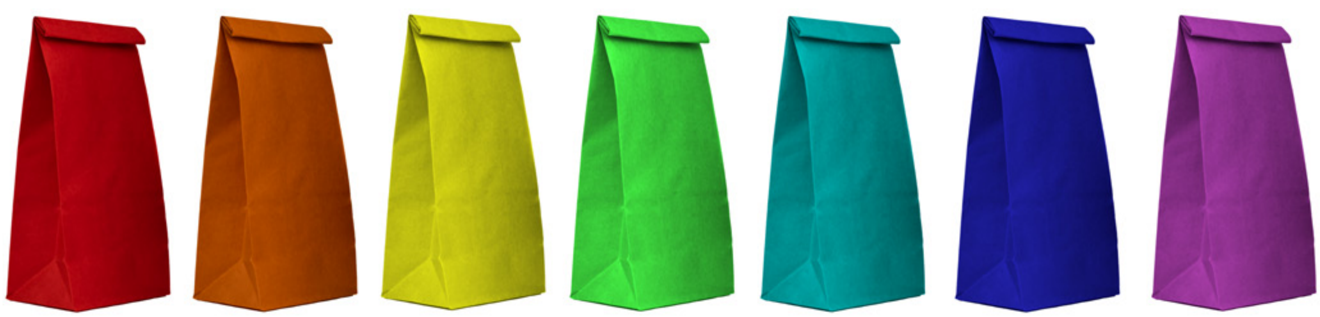

Figure 1 Use paper bags to represent molecules.

5.3A Froth flotation

CHALLENGE

Aim

To examine how froth flotation can be used to concentrate metal minerals.

What you need:

4 test tubes, test-tube rack, 4 test-tube stoppers, sample of crushed quartz, galena, distilled water, calcium chloride solution (collector), detergent

What to do:

1 Add 5 cm of distilled water to test tube 1.
2 Add a stopper to the top of the test tube and shake. Record your observations.
3 Add 10 drops of calcium chloride solution and 10 drops of detergent to the test tube.
4 Add a stopper to the top of the test tube and shake. Record your observations.
5 Repeat steps 1–4 with distilled water and crushed quartz samples.

Results

Table 1 Results table

Test tube	Test tube contents	Observations
1	Distilled water Distilled water + calcium chloride Distilled water + calcium chloride + detergent	
2	Distilled water + quartz Distilled water + quartz + calcium chloride Distilled water + quartz + calcium chloride + detergent	

Discussion

1 Describe the function of the detergent.
2 Describe the effect of the collector calcium chloride on the mixture.
3 Describe how this process could be used to concentrate the mineral in mining.

5.3B Electrolysis of copper sulfate

EXPERIMENT

Aim

To use electricity to produce copper metal from copper(II) sulfate through electrolysis.

Materials

- Copper(II) sulfate
- 100 mL beaker
- Stirring rod
- Spatula
- DC power supply
- 12V globe and globe holder
- Wires with alligator clips
- 2 carbon rods
- Gloves and safety glasses

Method

1 Add one spatula of the copper(II) sulfate to the beaker and half-fill it with water.

2 Stir until the crystals are all dissolved.

3 Set the power supply to a maximum of 6V and connect the circuit as shown in Figure 1.

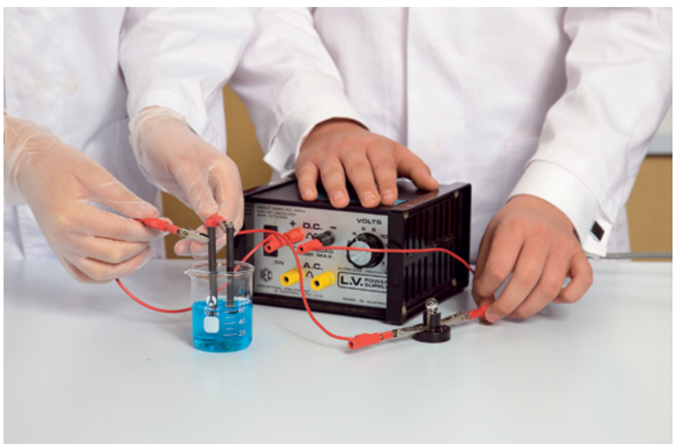

Figure 1 Connect the circuit.

4 Touch the carbon rods together to check the circuit works and then place the carbon rods in the beaker with a 1 cm gap between them.

5 Hold the rods in place for 30 seconds and observe any changes that occur.

6 Turn off the power supply.

Results

Record your observations in an appropriate format.

Discussion

1 Describe the evidence that copper was formed in the reaction.

2 Consider the structure of the copper sulfate when describing the:
   - role of the electricity
   - reason that the copper was only found on one of the carbon electrodes.

3 Evaluate if a usable amount of copper could be produced this way (by describing the amount of energy used and the amount of copper produced in the time and deciding if it would make an effective business model). If not, describe the changes that would need to be made to the set-up to produce more copper.

Conclusion

Describe what you know about electrolysis.

Figure 2 Copper sulfate

6.2 Modelling a carbon sink

CHALLENGE

CAUTION! Dry ice is frozen carbon dioxide (–79°C). Do not touch the dry ice with your fingers or metal objects. Use wooden or plastic tongs. Do not seal dry ice in any container because the gas expands rapidly.

This activity may be demonstrated by your teacher.

Aim

To model the effects of a carbon sink.

What you need:

Dry ice, 100 mL water, universal indicator, 200 mL beaker, piece of netting, watch glass that covers the top of the beaker, sticky tape, wooden or plastic tongs

What to do:

1 Place the water in the beaker.
2 Add 5 drops of universal indicator to the water.
3 Place the netting over the top of the beaker and push down the centre slightly. This will provide a pouch to suspend the dry ice above the water. Use sticky tape to hold the netting in place.
4 Place a piece of dry ice in the netting and place the watch glass over the top of the beaker.
5 Observe any colour changes in the water.

Discussion

1 Describe what happened to the solid dry ice when it was sitting in the netting.
2 Describe any changes you noticed in the water and universal indicator.
3 Identify the final pH of the water.
4 Provide an explanation for the changes you noticed.
5 Define the term 'carbon sink'.
6 Describe how you could use this demonstration to explain the consequences of increased carbon dioxide levels in the atmosphere.

Figure 1 Dry ice is frozen carbon dioxide.

6.3 Combustion and candles

CHALLENGE

Aim

To investigate the combustion reaction in a lit candle.

What you need:

Tealight candle, beaker large enough to fit over candle, matches

What to do:

1 Light the tea candle with a match.
2 Place the beaker over the candle and observe what happens.

Figure 1 Use a tea light and beaker to investigate combustion.

Questions

1 Identify the fuel for the chemical reaction occurring with the candle.
2 Explain why the candle goes out shortly after being covered with the beaker.
3 Describe the moisture on the inside of the beaker. Identify the source of this water.
4 Write a word equation for the combustion of the candle wax.

6.5 What factors affect a greenhouse?

EXPERIMENT

Aim

To determine which surfaces of the Earth absorb energy and radiate it as heat and so are likely to contribute most to the warming of the atmosphere.

Materials

- 3 cups of dark soil
- 3 cups of white sand or perlite
- White paint and brush
- Water
- 6 identical clear, empty 600 mL soft-drink bottles with labels removed
- 6 one-hole rubber stoppers with thermometers inserted that fit securely into the bottle top or data-logging equipment using long steel temperature probes with Blu Tack to secure the probe in place
- Sunlight or portable reflector lamp with 150 W floodlight bulb
- Funnel
- Stopwatch
- Marker pen
- Stand to support the lamp set-up (retort stand and clamps)

Method

1. Work as a group and label the bottles A, B, C, D, E and F. Paint the upper one-third of bottles B, D and F white to represent cloud cover.
2. Use a funnel to fill the base of bottles A and B with dark soil, bottles C and D with white sand or perlite, and bottles E and F with room-temperature water. Ensure that you use the same depth (5–7 cm) in each bottle.
3. Put the thermometers inserted in the rubber stoppers into the bottle tops. Ensure that the bulbs are just above the top of the dirt, sand/perlite and water. If the bulbs are below the base, they may record the heat absorbed directly by the soil or water, which will affect your data. You want to measure the temperature of the air (atmospheric). If using a data-logger temperature probe, secure and seal into the top of the bottle with Blu Tack.
4. Record the initial baseline atmospheric temperature of each bottle in a table.
5. If it is a sunny day, take your bottles outside. Alternatively, set up the 150 W light source on a stand facing down. Place the bottles underneath the light source approximately 15 cm away from the lamp. It is important that all bottles receive equal light. Depending on your light source, you may be only able to do two bottles at a time. If this is the case, ensure the two bottles have the same base; for example, dirt.
6. Record in an appropriate table, the temperatures of each bottle every 2 minutes for at least 20 minutes. Calculate the mean temperature of each bottle filling and record it in the table.

Results

Predict which bottle will reach the highest temperature and justify your prediction.

Draw a graph of time (in minutes) against the mean bottle temperature to record your observations.

Discussion

1. Use the graph to compare the rate of increasing temperature for the different bottles.
2. Identify which bottled environment:
   a. produced the lowest temperature
   b. would lead to the least heating of the atmosphere.
3. Explain the temperature difference between the dark soil and the white sand/perlite.
4. Explain the temperature difference between the water and the white sand/perlite.
5. Explain how this experiment demonstrates the effect of the oceans and dark and light surfaces on air temperature.
6. If the deserts are increasing and ice is melting, exposing dark soil, describe the expected effects this will have on atmospheric temperature.
7. Explain why each bottle filling was duplicated in this experiment.

Conclusion

Summarise your key findings from this experiment.

Figure 1 Water absorbs heat.

6.6 Measuring carbon farming

CHALLENGE

The key to measuring the amount of carbon stored in a tree is the size of the tree. Bigger trees are usually older and have therefore had more time to photosynthesise (capture carbon dioxide from the atmosphere). The size of the tree can be determined by the girth (circumference) of the tree at chest height (1.3 m above the ground)

Aim

To determine the amount of carbon stored in a tree.

What you need:

Calculator, tape measure

What to do:

1 Identify a tree in the grounds of your school.
2 Use a tape measure to measure the circumference of the tree at 1.3 m above the ground. Repeat this measurement two more times.
3 Calculate the mean girth of the tree.
4 Use Table 1 to determine the dry weight of the tree.

Table 1 The dry weight of trees according to their circumference

Circumference (cm)	Dry weight (kg)
50	106
100	668
150	1964
200	4221
225	5771
250	7641
275	9842
300	12 410
325	15 350
350	18 700
400	26 674

5 Half the dry weight of a tree is carbon. Divide the mean dry weight of the tree by 2.
6 Record the amount of carbon stored in the tree you measured.

Questions

1 Identify the name of the process used by the plant to extract carbon dioxide from the atmosphere.
2 Describe reactants and products in the chemical reaction you named in the previous question.
3 Calculate the amount of carbon dioxide that was absorbed by the tree to create this store by multiplying the amount of carbon stored by 3.67.
4 Describe what would happen to the carbon stored in the tree if it was chopped up for firewood.
5 Describe what would happen to the carbon stored in the tree if it was turned into furniture or used to build a house.

7.1A Investigating heating by convection

EXPERIMENT

Aim

To investigate heating water by convection.

Materials

- Water
- Potassium permanganate crystals (or a few drops of food colouring)
- Bunsen burner
- Tripod
- Heatproof mat
- 600 mL beaker
- Dropper or pipette

Method

1 Set up the experiment as shown in Figure 1.

2 Fill the beaker with water. Put individual crystals of potassium permanganate on the bottom of the beaker, at the edge. Alternatively, add a drop of food colouring to the bottom of the full beaker using a dropper or pipette.

3 Heat the water gently over the Bunsen burner and observe the movement of the crystals. (If possible, use a small flame and no heatproof mat between the Bunsen burner and the beaker – you can do this with Pyrex beakers.)

4 Note the path that the coloured water takes from the burner to the top of the water and back down again.

Results

Draw a labelled diagram showing the movement of the coloured water.

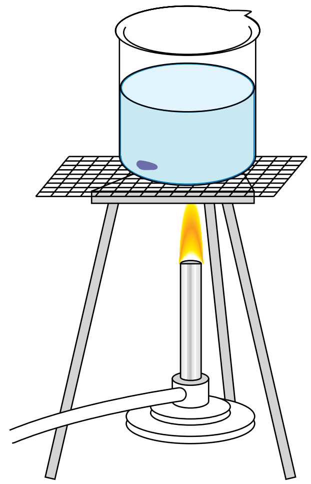

Figure 1 Experimental set-up

Discussion

1 Define the term ‘convection’.

2 Define the term ‘conduction’.

4 Describe the movement of the coloured water.

5 Use the terms conduction and convection to explain how the movement of water particles changes as they are heated.

6 Use the movement of the particles in the water to explain the movement of the coloured water.

7 Plan an experiment to test the scientific question ‘What if?’

Conclusion

Describe what you know about heating water by convection.

7.1B Testing insulating materials

EXPERIMENT

Different materials have different thermal properties. The ability of a material to resist the transfer of thermal energy is called the R-value of the insulation. The higher the R-value, the more it is able to resist the flow of thermal kinetic energy and the better an insulator it will be.

Aim

To test the insulating properties of different materials.

Materials

- 5 × 50 mL beakers
- 5 ice cubes (approximately the same size from ice trays)
- Stopwatch
- Low temperature hot plate
- Scales
- A variety of different materials with insulating properties (newspaper, tissues, newspaper, cotton balls, Styrofoam, aluminium foil, petroleum jelly, Cheetos, etc.)

Method

1 Write a hypothesis identifying which materials will have the highest R-value.

2 Select 4 materials to test.

3 Add 2 cm of each material to the bottom of an individual beaker. Leave the fifth beaker without any material in the base.

4 Turn the hot plate on a low temperature. Place each beaker on the hot plate so that they are exposed to the same amount of thermal energy.

5 Weigh and record the mass of each ice cube.

6 Place a single ice cube in the centre (on top of the materials) of each beaker.

7 Leave the ice cubes exposed to the thermal energy for 20 minutes.

8 Weigh the final mass of each melted ice cube.

9 Calculate the change in mass of each ice cube.

Results

Draw a table to record the initial mass, final mass and change in mass of each ice cube.

Discussion

1 Define the phrase 'thermal insulator'.

2 Describe how the thermal energy of the hot plate was transferred to the ice.

3 Describe how the thermal energy affected the water particles in the ice.

4 Identify the material that had the:

 a highest thermal insulating property

 b lowest thermal insulating property.

5 Design a valid experiment that would investigate the question 'What if the amount of thermal insulator was doubled?'

Conclusion

Describe what you know about the insulating properties of the different materials used in this experiment.

7.2 Modelling sound waves

CHALLENGE

Aim

To explore sound waves and frequencies.

What you need:

Slinky spring, pipe cleaner

What to do:

1 Twist a pipe cleaner around a single curl in the slinky spring so that the rest of the spring can move easily.
2 Two people slowly stretch the spring out along the floor – slightly beyond its normal length. Allow the spring's movement to become still.
3 One person pushes their end of the spring firmly forwards, towards the other person, and then returns it to the rest position. This will create areas where the coils are pushed together (compressions) and areas where the coils are stretched out (rarefactions).

   These areas will travel along the spring to the other end. The person at the other end needs to hold the spring firmly and still.
4 Try to make the wave have more or less energy by pushing the end faster, while keeping the length of the wave the same. This is the same as making a sound louder. Pushing less models a softer sound.
5 Try to change the frequency (number of waves per second) of your wave. Try to create 4 waves per second (a higher frequency) and 0.5 waves per second (a lower frequency).
6 Draw labelled diagrams of the waves you created, carefully indicating how the waves show that different frequencies have been achieved.

Questions

1 Describe how far the pipe cleaner moved as the wave moved along the spring.
2 Describe what happened when the wave reached the other end of the spring.
3 Compare the model wave bouncing back from a hard surface to an echo.
4 Describe how the model can be used to represent higher frequency sound waves.
5 Explain how the distance between the compressions is affected in lower frequency waves.

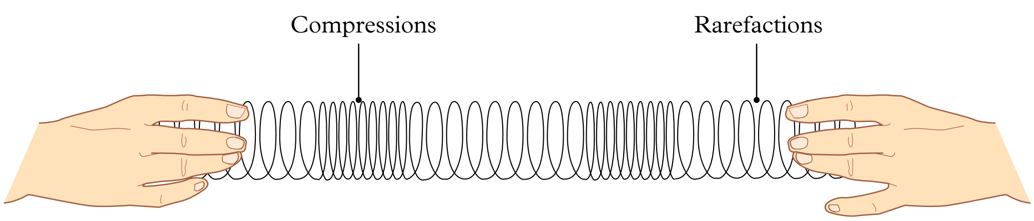

Figure 1 Experimental set-up

7.3A The speed of sound

CHALLENGE

Aim

To explore the speed of sound on the school oval. (This is a whole-class activity.)

What you need:

Tape measure or trundle wheel, stopwatches, 'slap sticks' (or two large sticks that make a sound when hit together)

What to do:

1 On the school oval, measure a distance of 100–200 metres.
2 One person takes the slap sticks to the far end of the measured distance. When everyone is ready, slap the sticks together to make a noise.
3 The rest of the class should start their stopwatches when they see the sticks hit together and stop them when they hear the 'slap'.
4 Repeat this measurement five times.
5 Record your measurements in a table.

Figure 1 Use a stopwatch to measure the speed of sound.

Questions

1 Explain why you need to repeat this measurement many times.
2 Calculate the average amount of time it took for sound to travel the measured distance.
3 Use the formula:

$$\text{Speed} = \frac{\text{distance travelled (m)}}{\text{time (s)}}$$

to calculate the approximate speed of sound.
4 Compare your measurement to the accepted value of 340 m/s. Explain any differences between the two measurements.

7.3B Racing dominoes

CHALLENGE

Aim

To identify whether sound will travel faster in gas or liquid.

What you need:

Large set of dominoes, metre ruler

What to do:

1 Set up two rows of dominoes 1 metre long on the floor (Figure 1). One set of dominoes should be spaced far apart from each other (but still close enough to knock each other over) while the second set of dominoes are much closer together.

2 Use the metre ruler to knock over the first domino of each row at the same time.

Questions

1 Identify which row of falling dominoes reached the finish line first. Explain a possible reason for this result.

2 Compare the space between the dominoes in rows 1 and 2 to the space between the particles of liquids and gases.

3 Use the evidence from your model to identify whether sound will travel faster in gas or liquid.

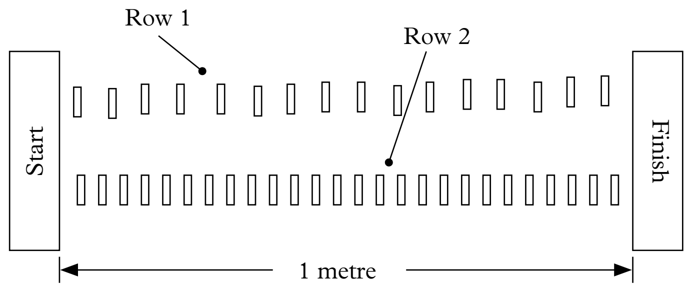

Figure 1 Experimental set-up

7.4A Demonstrating electrostatics

CHALLENGE

Aim

To model and explain electrostatic electricity.

What you need:

Plastic comb, woollen cloth, Rice Bubbles, large plastic bag with tie, plastic rod or pen, small pieces of paper, balloons, balloon pump, felt-tipped pens, string, tape

PART A

What to do:

1 Place some of the Rice Bubbles in the plastic bag. Blow air into the bag and seal it with the tie.

2 Rub the woollen cloth over both the plastic bag and the comb.

3 Bring the plastic bag and comb together.

4 Record what happens.

5 Explain your observations, using the idea of electrostatic charge.

PART B

1 On a piece of paper, draw four positive and four negative charges. Show what happens to these charges when the positively charged woollen cloth is brought close to them.

2 Explain why the paper is attracted to the plastic rod or pen by discussing the movement of charges.

PART C

1 Using the balloon pump, blow up a balloon and carefully draw a face on it.

2 Tie the balloon onto a string and suspend it from a doorway or ceiling using tape, so that it is level with your head.

3 Rub the balloon face with the woollen cloth and walk towards it.

4 Record what happens.
   - Identify the distance from the 'balloon face' you have to be before it is attracted to you.
   - Describe what happens if you put a piece of paper between you and the balloon.

5 Blow up another balloon and draw a face on it.
   - Describe what happens when you bring it close to your suspended balloon.

Questions

1 Describe your observations in Part A using the terms 'like charges', 'unlike charges' and 'neutral or no charge'.

2 Describe your observations in Part B using the terms 'like charges', 'unlike charges' and 'neutral or no charge'.

3 Describe your observations in Part C using the terms 'like charges', 'unlike charges' and 'neutral or no charge'.

Figure 1 Can you explain the attraction of the balloon?

7.4B Separating charges with a van de Graaff generator

CHALLENGE

Aim

To use a van de Graff generator to demonstrate electrostatic electricity.

What you need:

Paper streamers, van de Graff generator, smaller sphere connected to discharge wand, small pieces of paper, aluminium plates, paper cup with Rice Bubbles

What to do:

1 Observe what happens to objects that have been charged by a van de Graaff generator. Record your observations in a table.

2 Your teacher may demonstrate any of the following:

   a a smaller sphere held near a larger sphere

   b paper streamers attached to the top

   c paper streamers held nearby

   d long dry hair nearby

   e small pieces of paper thrown on top

   f aluminium plates placed on top

   g paper cup with Rice Bubbles inside.

Questions

1 Describe the three rules of electrostatic charges.

2 Explain what happens in each example, using your knowledge of electrostatic charge.

Figure 1 What happens to paper streamers?

7.5 Making series and parallel circuits

CHALLENGE

Aim

To compare the current in series and parallel circuits.

What you need:

2 × 1.2 V globes and holders, 1.5 V battery and holder, 8 connecting wires (with banana plugs or alligator clips), switch, ammeter or multimeter

What to do:

1 Construct four circuits, placing the switch so that it controls:
   a both globes, with both either on or off at the same time
   b one globe only, with the other on all the time
   c the other globe only, with the first globe on all the time
   d both globes, with one globe on when the other is off and vice-versa.

   Complete step 2 before you disconnect each circuit.
2 Draw the circuit diagram to show where the switch was placed in each circuit.
3 Connect an ammeter at different places in each circuit and measure the current at each point.

Questions

1 Describe the effect of changing the location of the switch in a simple circuit.
2 Define the term ‘current’.
3 Describe how an ammeter should be connected to measure the current in a circuit.
4 Describe how the current did or did not change when the ammeter’s location was changed.

Figure 1 How many ways can you connect multiple globes in a circuit?

7.6A Using Ohm's law to find resistance

SKILLS LAB

Aim

To use Ohm's law to determine current, voltage and resistance.

Example

Find the value of a resistor that has a voltage drop of 6 V across it when a current of 50 mA flows through it.

1 Check the units: 6 V is in volts and so can be used unchanged. You will need to convert 50 mA (milliamps) to amps. The prefix 'milli' means 0.001 (or $\times 10^{-3}$), so 50 mA = 50 × 0.001 or 0.05 A.
2 Use the Ohm's law triangle to find the correct formula. You want to find resistance, so use your fingertip to cover the R – the other two letters show you the formula to use (Figure 1).
The V is over the I, so use:

$$R = \frac{V}{I}$$

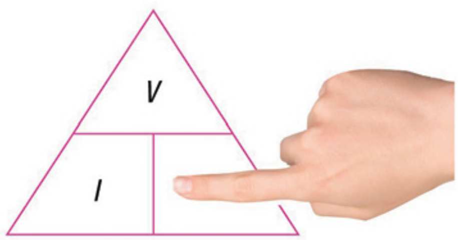

Figure 1 Using the Ohm's law triangle

3 Substitute the numbers for V and I:

$$R = \frac{6}{0.05}$$

4 Do the calculation: 6 ÷ 0.05 = 120 Ω.

Your turn

This law can also be used to work out the voltage or the current.

1 Calculate the voltage drop across a resistor with a value of 180 Ω and a current of 50 mA. (Remember to cover V in the Ohm's law triangle to get the correct formula for R and I. If the letters are next to each other, multiply them.)
2 If a 12 V battery is placed in a circuit with a 470 Ω resistor, calculate the current that will flow through the circuit.
3 If the current of a circuit with a 12 V battery is 0.004 A, calculate the resistance of the circuit.

7.6B Understanding resistor colour codes

SKILLS LAB

Aim

To use the coloured banding of a resistor to determine its value.

What you need:

A selection of coloured resistors

What to do:

Carbon resistors typically have four colour-coded bands on their case (Figure 1). These bands are part of a code that allows you to work out their approximate value and tolerance. The fourth band is the tolerance band, which indicates the amount that the resistance may vary by (the relative accuracy of the resistor). Gold means 5 per cent tolerance, silver means 10 per cent tolerance, and no fourth band means 20 per cent tolerance. The lower the percentage tolerance, the more accurate (or closer to the true value) the resistor is.

Figure 1 A resistor with colour-coded bands

To read the three other bands, put the tolerance band on the right and start at the other end. The first two bands form a two-digit number according to their colour (see Table 1). The third band tells you how many zeros to put after the number.

Table 1 Resistor colour codes

Colour	Value
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Grey	8
White	9

Look at the resistor in Figure 2. What does its code mean?

1 The tolerance band is gold, so the resistor has 5 per cent tolerance.
2 The first band is blue, so it has a value of 6.
3 The second band is red, so it has a value of 2. The number is now 62.
4 The third band is also red, so this means 2 zeros need to be added to the number. The number is now 6200.
5 Resistor values are always coded in ohms, so the value of this resistor is 6200 ohms or 6.2 kilo-ohms.

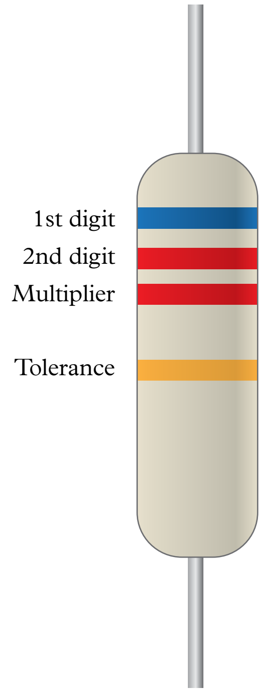

Figure 2 Calculate the value of this resistor.

Collect a resistor from your teacher and use the coloured bands to determine its value.

Discussion

1 Define the electrical term 'resistance'.
2 Explain why different resistors may need to be used in different circuits.
3 Explain what is meant by the term 'tolerance'.

7.6C Investigating Ohm's law

EXPERIMENT

Aim

To investigate the voltage drop across and the current flow through a resistor, and to calculate an average value of the resistance.

Materials

- 2–12 V power supply
- Ammeter
- Voltmeter
- 10 Ω resistor
- 3 other resistors with masking tape over their coloured bands
- Connecting wires

Method

1 Identify the 10 Ω resistor. It should be colour-coded brown, black, black.
2 Connect the circuit as shown in Figure 1. Use the DC terminals of the power supply and start with the dial on 2 V.
3 Switch on the power supply, take the readings on the ammeter and voltmeter, and switch the power off again straight away (so you don't overheat the resistor).
4 Change the dial on the power supply to 4 V and repeat step 3. Then change the dial to 6 V and repeat.

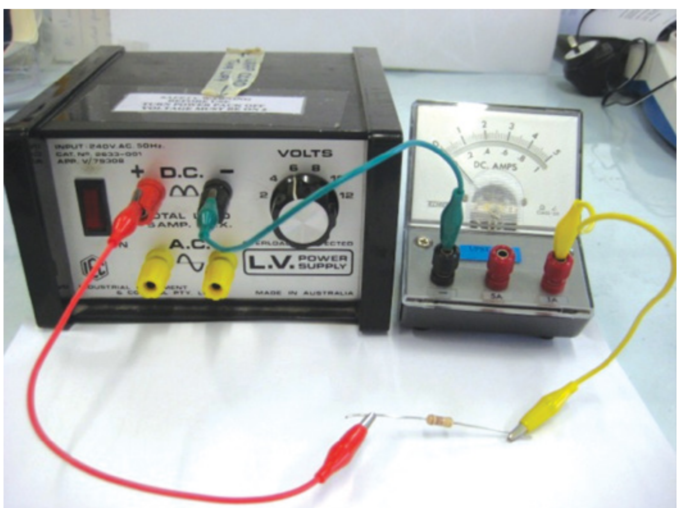

Figure 1 Circuit set-up

5 Record your results in Table 1.

Table 1 Experiment results

Resistor	Voltage (V)	Current (mA)	Volts ÷ amps

6 Repeat the experiment for the other three resistors, without reading their coloured bands.
7 Complete the results table for each of the three masked resistors and calculate their resistance.
8 Remove the masking tape and determine the resistance values from the coloured bands of the resistors.

Results

Include your results table.

Discussion

1 From your results table, identify what the values in the last column calculate.
2 For the three masked resistors, compare the accuracy of the values you obtained to the values indicated by their coloured bands.
3 Use the formula below to calculate the difference (error) between the two values as a percentage of the marked value.

$$\% \text{ error} = \frac{\text{marked value} - \text{average calculated value}}{\text{marked value}} \times 100$$

4 Identify which value – the one obtained by reading the coloured bands or the one obtained from your calculations – provides the most useful measure of a resistor's resistance. Justify your answer (by explaining how each value is obtained, describing which value is most relevant to use in a circuit and deciding which value provides the most useful measure).

Conclusion

Describe what you know about Ohm's law.

7.7 Modelling light waves

CHALLENGE

Aim

To model and explore light waves.

What you need:

Slinky spring, clear space on the floor

What to do:

1. Two people hold the spring, one at each end. On the floor, slowly stretch the spring out slightly beyond its normal length. One person flicks their end of the spring firmly to one side. This will create a sideways 'pulse' in the spring. The other person needs to hold the spring firmly and still. The pulse will travel along the spring to the other end (Figure 1).
2. Continue flicking the spring to create a continuous transverse wave. Identify the peaks and troughs of the wave.
3. Make the wave have more or less energy by changing how hard you flick the end. Try to keep the speed of the wave the same.
4. Increase the number of waves per second. You have just modelled a wave of higher frequency.
5. Try to reduce the number of waves. This model represents a lower frequency wave.
6. Draw labelled diagrams of a high frequency wave and a low frequency wave. Identify the wavelength in each diagram.

Questions

1. Describe how you modelled higher frequencies with your model light waves.
2. Explain how increasing the frequency affects the distance between the peaks of the wave (wavelength).
3. Identify another example of a transverse wave that exists in the real world.

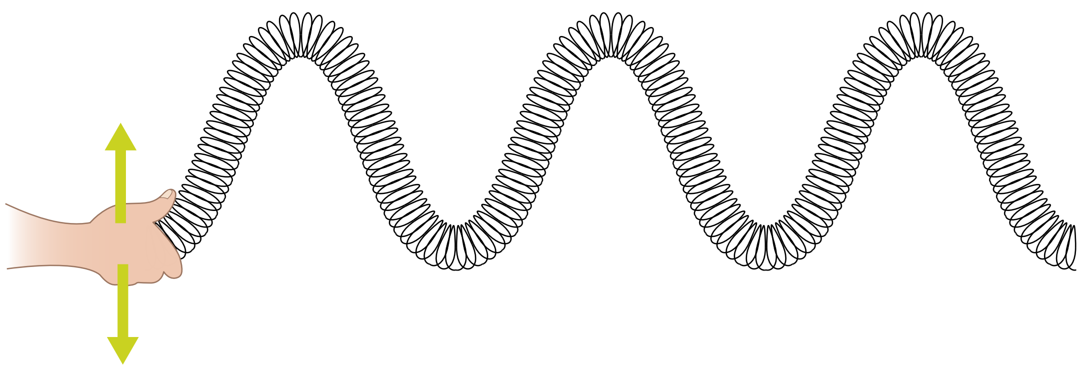

Figure 1 Flicking the slinky creates a pulse.

7.8A Using a Hodson light box

SKILLS LAB

Aim

To learn how to use a Hodson light box.

What you need:

A Hodson light box, sheet of white A4 paper, pencil, ruler

What to do:

1 Place the light box on a piece of white A4 paper.

Figure 1

2 Plug the light box into either the AC or DC sockets of a power supply. The voltage dial controls the brightness of the light globe.

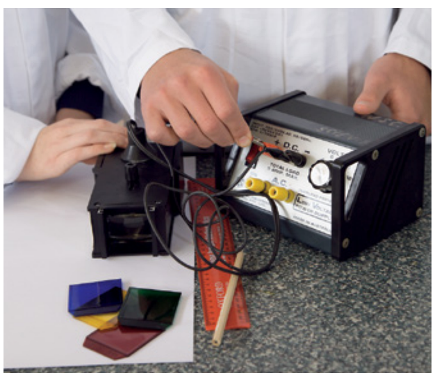

Figure 2

3 Slide a slot former into the opposite end of the light box to where the mirror flaps are. Usually a single-slot or a three-slot former is used.

Figure 3

4 Aim the light ray at the target, in this case a plane mirror.

Figure 4

5 Use a sharp pencil to mark the incident and reflected rays with dots.

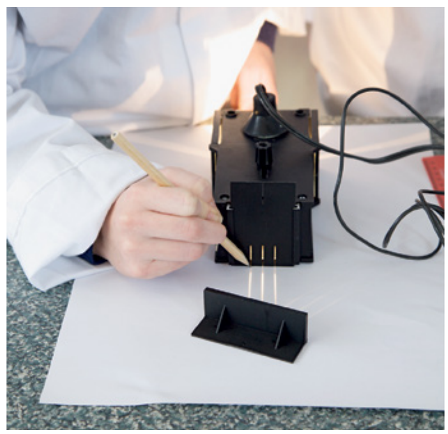

Figure 5

6 Remove the light box and join the dots with thin, straight pencil lines.

Figure 6

7.8B Reflection from plane mirrors

EXPERIMENT

Aim

To investigate the law of reflection: the angle of incidence equals the angle of reflection.

Materials

- Hodson light box kit
- Power supply
- Sheet of white A4 paper
- Plane mirror from light box kit
- Blu Tack
- Ruler
- Pencil
- Protractor

Method

1. Rule a straight line in pencil centrally across the width of the A4 paper. The mirror surface will be placed along this line.
2. Use the protractor to construct a normal line at 90° in the centre of the first line.
3. Position the back edge of the plane mirror along the first pencil line. Keep it in place with Blu Tack.
4. Set up the Hodson light box, darken the room and aim a single incident ray at the centre of the mirror where the normal begins. Mark the position of the incident and reflected rays with pencil dots.
5. Move the light box to a different angle and aim another incident ray so that it hits the mirror at the same place as it did the first time. Mark the incidence and reflection rays by drawing arrows. Label the lines A.
6. Repeat step 5 until five sets of lines are obtained. Label each set of lines B, C, D, etc.

Results

1. Remove the light box and rule lines to show the straight path of the incident and reflected rays.
2. Carefully use the protractor to measure the five angles of incidence and the five angles of reflection for each set of lines A, B, C, etc.
3. Move the protractor so that the 0° of the protractor is along the normal. Read the angle between the normal and each incident ray, and between the normal and reflected rays.
4. Record your results in a suitable table.

Discussion

1. Explain why the back edge and not the front edge of the plane mirror should be lined up on the pencil line.
2. Compare your angles of incidence to your angles of reflection. Explain how they support the law of reflection.
3. List two possible sources of error in this experiment.
4. Describe what happened when you directed the light at right angles to the mirror.
5. Explain whether the law of reflection is still obeyed if the angle of incidence is 0°.
6. List at least three examples where you have observed the law of reflection in action.

Conclusion

Describe what you know about the relationship between the angle of incidence and the angle of reflection.

7.8C Mirror writing

CHALLENGE

Aim

To discover the level of difficulty involved in using mirror reflection.

What you need:

Large plane mirror, logbook/workbook, pencil

Figure 1 Discover how difficult it is to perform tasks using mirror reflections.

What to do:

1 Hold a large plane mirror in front of your page in your logbook and try to write your name so that it is legible in the mirror. Practise with other words until you get good at this.

2 In some countries, ambulances have their name spelt backwards so drivers can see it in their rear-view mirror. See if you can work out how to write the word 'ambulance' backwards in capital letters so it would read correctly when viewed this way. Have a friend hold the word up behind you and hold the mirror up in front of your eyes.

3 Draw a short maze, then attempt to guide your pen through the maze by only looking in the mirror. A friend could cover the real maze so you are not tempted to look. Just look in the mirror.

Questions

1 Contrast the level of difficulty in the three activities.

2 Describe how practice will change the level of difficulty of these tasks.

7.8D Using curved mirrors

CHALLENGE

Aim

To investigate the behaviour of curved mirrors.

What you need:

Convex mirror, concave mirror, pen, Hodson light box kit

What to do:

1 Place an object, such as a pen tip, close to the convex mirror and observe the image. Try to describe the nature of the image.
   > Upright or inverted (upside down)?
   > Larger (magnified) or smaller (reduced) than the object?
   > Real (capable of being captured on a screen or piece of paper) or virtual?

2 Move the object further from the mirror and repeat your observations.

3 Repeat step 1 with a concave mirror. It is possible to form a real image with a concave mirror and there is more variation in the nature of the image as the object is moved further from the mirror.

4 Summarise your findings in a table that compares the two types of mirrors.

5 Use the Hodson light box kit to investigate curved mirrors. There should be a convex and concave mirror in the kit. Use the three-slot former in the kit to draw diagrams of the incident and reflect rays for both types of curved mirrors.

Discussion

1 Identify the mirror that converges (brings together) the rays.

2 Identify the mirror that diverges (spreads apart) the light rays.

3 Describe how your appearance would change if you viewed your image in concave and convex mirrors.

4 Describe how a shop uses mirrors to make their clothes and clients look thinner.

Figure 1 The type of curve on a mirror affects its behaviour.

7.9A Bending of light

EXPERIMENT

Aim

To investigate the path of light rays during the process of refraction.

Materials

- Hodson light box kit
- Power supply
- Sheet of white A4 paper
- Perspex block from light box kit
- Blu Tack
- Ruler
- Pencil
- Protractor

Method

1 Place the Perspex block in the centre of the A4 paper. Trace around the outside of the Perspex block with your pencil.
2 Remove the block and use the protractor to construct a normal at 90° to one of the long sides of the block.
3 Position the block on the paper again. Keep it in place with a thin amount of Blu Tack.
4 Set up the Hodson light box, darken the room and aim a single incident ray at the face of the block at the normal line. Draw the incidence and reflection ray using arrows to identify each.
5 Move the light box so that the ray is aimed at the face of the block at an angle of approximately 45°. Mark the position of the incident ray and the ray that exits the block on the other side with pencil dots. Ignore any reflected rays at this time.
6 Remove the block and turn off the light box. Use a ruler to draw the straight rays that you identified.

Results

1 Join the end of the incident ray to where it exits the block on the other side. Construct a normal to the face of the block where the ray exits.
2 Use the protractor to measure the four angles on your diagram. Line up the 0° line of the protractor along the normal each time and read the angles between the normal and incident rays and between the normal and the refracted rays. Record your results in two tables for refraction from air to Perspex and refraction from Perspex to air.

Discussion

1 Explain your observation when the incident light travelled along the normal.
2 Compare your angles of incidence to your angles of refraction as the light entered the Perspex block. Explain your observation.
3 Compare the size of the angle at which the light hit the glass block with the angle at which it leaves.
4 Identify which medium is most dense (air or the Perspex block).
5 Describe how the light ray moved (towards or away from the normal) as it moved into the Perspex block, and as it left the Perspex block.
6 Compare your results to the expected refraction of light.
7 Identify two possible sources of error in this experiment.

Conclusion

Describe what you know about the path of light rays during the process of refraction.

7.9B Creating images with convex lenses

EXPERIMENT

Aim

To investigate the behaviour of a convex lens and the nature of the image produced at different object–lens distances.

Materials

- Hodson light box kit
- Candle
- Matches
- Convex lens
- Lens holder
- Rulers (30 cm, 1 m)
- White paper screen
- Blu Tack

Method

1 Determine the focal length of the lens by placing the lens on a piece of paper and shining three rays of light through it so the light converges into a single focal point. Measure the distance from the centre of the lens to the focal point. This is the focal length *f*. Double the focal length. This is called 2*f*.

2 Light the candle. Mount the lens in the lens holder and check to see if the centre of the lens is in line with the candle flame. If not, raise it to the correct height.

3 Darken the room and position the lens at a distance of more than twice the focal length from the candle flame (the object). Try to capture an image on the paper screen by moving the screen slowly until a focused image of the candle is formed. Describe the size of the image compared to the object (magnified, same size or reduced), the type of image (real or virtual) and the orientation of the image (inverted or upright).

4 Move the lens closer to the candle so that the object–lens distance is between *f* and 2*f*. Repeat your observations.

5 Repeat for the other lens positions in the results table. In some cases, the image may not form on the screen. Instead, it can be found by looking into the lens towards the candle flame. This will be a virtual image. In one case, there may be no image – real or virtual.

Results

Complete Table 1.

Discussion

1 Describe when the lens produced a real image and when it produced a virtual image.

2 Explain any other observations you made or ask your teacher about them.

3 Compare your results with those of other members of the class.

4 Identify one way you could improve your method to produce more reliable results.

Conclusion

Describe what you know about the behaviour of a convex lens and the images it produces.

Table 1 Results table

Object–lens distance	Size of image	Type of image	Orientation of image	Any other observations
Larger than 2*f*				
Equal to 2*f*				
Between *f* and 2*f*				
Equal to *f*				
Less than *f*				

7.10 What colour is it?

EXPERIMENT

Aim

To investigate the addition of coloured light and explore the behaviour of coloured filters.

Materials

- Hodson light box kit
- Power supply
- Sheet of white paper

Method

1 Connect the light box to a power supply and place it on the sheet of paper.

2 Place the three primary filters (red, green and blue) in each of the three separate slotted sections in the light box. Adjust the mirror flaps so that the colours can overlap on the paper. Change the combination of filters and copy and complete Table 1.

Table 1 Results for primary colour filters

Addition of primary colours	Colour produced
Red + green + blue	
Red + blue	
Green + blue	
Red + green	

3 Replace one of the primary filters with the secondary filters (yellow, cyan and magenta) and copy and complete Table 2.

Table 2 Results for a combination of primary and secondary colour filters

Addition of colours	Colour produced
Yellow (side slot) + blue (front slot)	
Magenta (side slot) + green (front slot)	
Cyan (side slot) + red (front slot)	

4 Switch off the light box and remove the filters. Select a red, green, blue and yellow oblique surface from the light box kit. Hold each of the coloured surfaces against the back of each primary filter. Record in Table 3 the colour that each surface appears.

Table 3 Results when viewing the colour of surfaces through primary colour filters

Surface colour	Colour surface appears when viewed through a:		
	Red filter	Green filter	Blue filter
Red			
Green			
Blue			
Yellow			

Discussion

1 Identify the combinations of colours that produce white light.

2 Describe any patterns you observed in each of the tables. Explain the patterns you observed.

3 Identify one possible source of error in the experiment.

4 Describe the difficulties you had, and how you overcame them.

Conclusion

Describe what you know about what happens when coloured lights are added to each other.

Figure 1 Coloured filters

7.11 What is the wavelength of a microwave?

EXPERIMENT

CAUTION! Some students might have egg allergies.

Aim

To determine the wavelength of a microwave.

Materials

- Microwave oven with the turntable removed
- Large flat plate at least 20 cm in diameter (safe for use in a microwave) or piece of black cardboard approximately the same size
- Oven mitts
- Egg white
- Ruler

A microwave oven uses electromagnetic waves to heat food. These waves move through the cooking area in a set fashion. All microwave ovens have turntables to rotate food so that it cooks evenly. This is because of the wavelike motion of the energy. Without the turntable, the energy is focused in fixed parts of the oven.

You can use this to determine the wavelength of the microwaves in your microwave oven.

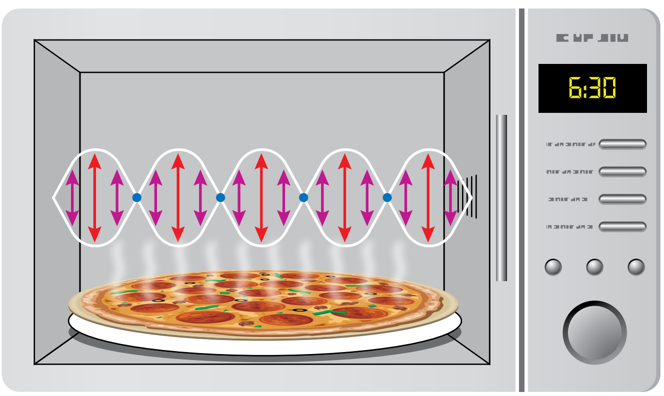

Figure 1 A microwave oven uses electromagnetic waves to heat food.

Figure 2 A microwave oven with the rotating platter removed and drive mechanism removed

Method

1. Crack the egg and separate the egg white from the egg yolk.
2. Spread the egg white evenly over the plate or black cardboard.
3. Place the plate/cardboard in the oven and turn on for 15–30 seconds (depending on the power of the microwave). The egg should start cooking in stripes/patches.
4. Remove the plate/cardboard from the microwave and identify the centre of the cooked stripes/patches. Measure the distance between two of the cooked patches.
5. Repeat this experiment several times and determine an average distance between the cooked egg white.

Figure 3 Use the cooked portions of the egg white to measure the distance between 'hot spots' in the microwave oven.

Results

1. Record all your observations in a table.
2. Multiply the average distance between the cooked egg white by 2 to determine the length of a full wavelength.

Discussion

1. Identify the wavelength of the microwaves in your microwave oven.
2. Describe any difficulty you had when determining the centre of the cooked portion of egg. Calculate the error margin of your calculation (± the width of the cooked egg bands).
3. Explain why you needed to repeat your experiment several times.

Conclusion

Explain what you know about the wavelength of microwaves.

8.3 Design an energy-efficient house

CHALLENGE

Design brief

Design and build two identical houses out of cardboard or wood. Add a feature to one of the houses that will make it more efficient in staying cool. Test your design feature by exposing both houses to an energy source (a strong light) and determine the rate of temperature increase for each house.

Criteria restrictions

- Only one feature may be added to the second house.
- The feature must represent a design feature that is currently available to homeowners.
- The feature must be proportionate in size to the house.

Questioning and predicting

- Identify the feature you will add.
- Identify the materials you will use.
- Use your knowledge of heat energy to explain why your added feature will keep the house cool.

Planning and conducting

- Explain how you will measure the temperature of the two houses.
- Describe how long you will expose the houses to the energy source.

Processing, analysing and evaluating

1. Describe the rate of temperature increase in both houses.
2. Describe how efficient your feature was at preventing the transfer of thermal energy.
3. Describe the limitations of your design (when it will not prevent thermal transfer).
4. Describe how you could create a large-scale version of your design for a real house.
5. Describe how you would modify your device if you were doing this experiment again.

Communicating

Present the various stages of your investigation in a formal experimental report.

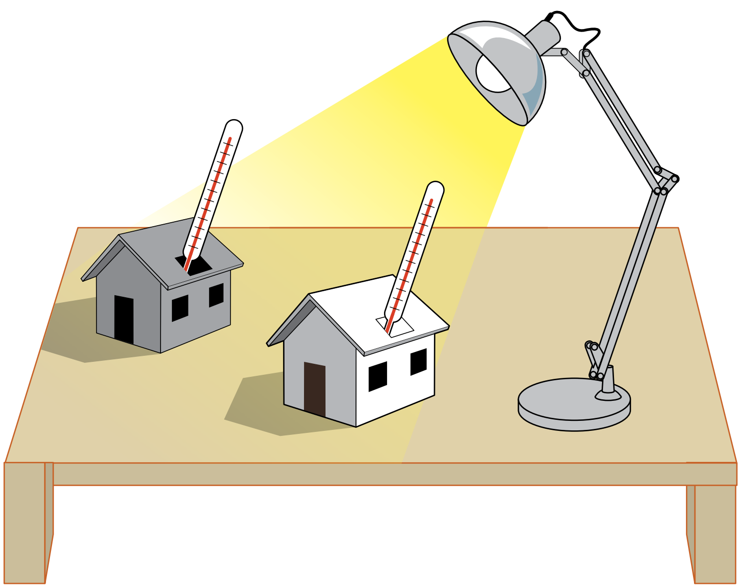

Figure 1 General set-up of experiment

[STEAM project 1]

How can we use sustainable farming practices so that no one goes hungry in the future?

The United Nations ranks food shortages and hunger among the most serious issues affecting humankind. It predicts that more than 840 million people will be hungry by 2030. Even in a high-income country such as Australia, 5 per cent of the population are unable to access enough nutritious food. The experience of having inadequate access to food, or having an inadequate supply of food, is known as food insecurity. Food insecurity is linked to poor general health, higher rates of some cancers and higher mortality.

Rapid climate change is increasing threats to Australia's and the world's food security. Changes in the amount of rainfall, longer droughts and an increase in the number of extreme weather events are expected to disrupt the amount and quality of food that Australia can produce. A hotter climate is expected to cause stress in livestock animals such as chickens, sheep and cattle, and to increase the amount of water needed for crop irrigation.

Sustainable farming

Sustainable farming practices use methods that balance the needs of all members of the community. This means that new and old technologies are used to make sure that food production is:

- economically viable – if farmers cannot make enough money to survive, then the farming practice is not sustainable
- socially supportive – if the lifestyle of the farming community is not supported, then people will not want to live in the area
- ecologically sound – if the local environment is not supported, then the land will be unable to support food production. Sustainable farming also works to maintain the diversity of the local wildlife.

Sustainable farming uses technology to increase the production of fresh, nutritious food while minimising the impact on the local environment.

Your task

Increase the growing capacity (productivity) of a 1 hectare (100 m × 100 m) plot of land by designing a vertical garden that won't damage the local environment.

Figure 1 Vertical farming allows people to grow more food in a smaller space.

Figure 2 Drought impacts Australia's production of important crops, such as wheat.

HUMANITIES

In Geography this year, you will learn about food security around the world and food production in Australia. You will investigate the factors that influence crop yield (such as soil moisture) and how food production can alter a biome. In Economics and Business, you will study the agricultural resources (such as wheat) that form a large part of Australia's trade economy.

To complete this task successfully, you will need to investigate the environmental constraints on agricultural production in Australia, such as climate and distribution of water resources. You will also need to understand the extent to which agricultural innovations have overcome these constraints.

You will find more information on this in Chapter 3 'Food security', Chapter 2 'Biomes' and Chapter 14 'Understanding the economy' of *Oxford Humanities and Social Sciences 9 Australian Curriculum*.

MATHS

In Maths this year, you will build on your knowledge of measurement and geometry to determine areas and volumes of more complicated shapes. You will study right-angled triangles using Pythagoras' theorem and trigonometry. You will also extend your skills in collecting, representing and investigating data.

To complete this task successfully, you will need to perform calculations involving angles, lengths and areas of two-dimensional and three-dimensional shapes. You will need to apply your understanding of scale factors to build a prototype of your designed product. To consider the situation at local, national and international scales, you will need skills in dealing with ratios and proportions. You may also find it helpful to use scientific notation for very large or very small numbers.

You will find help for applying these maths skills in Chapter 5 'Measurement', Chapter 6 'Geometry', and section 1E 'Scientific notation' of *Oxford Maths 9 Australian Curriculum*.

SCIENCE

In Science this year, you will learn about the carbon cycle and the ways human activity can disrupt it. You will also consider the consequences of disruption, including the enhanced greenhouse effect. You will also learn about asexual reproduction and investigate vegetative propagation.

To complete this task successfully, you will need to understand the factors required to keep a system, such as a vertical garden, alive. You may need to consider how these factors can be monitored and controlled automatically. You will also need to be familiar with the scientific method, and understand how to conduct a fair test.

You will find more information on this in Chapter 3 'Reproduction' and Chapter 6 'The carbon cycle' of *Oxford Science 9 Australian Curriculum*.

The design cycle

To successfully complete this task, you will need to complete each of the phases of the design cycle.

Discover

When designing solutions to a problem, you need to know who you are helping and what they need. The people you are helping, those who will use your design, are called your end-users.

Consider the following questions to help you empathise with your end-users:

- Who am I designing for?
- What problems are they facing? Why are they facing them?
- What do they need? What do they not need?
- What does it feel like to face these problems?

To answer these questions, you may need to investigate using different resources, or even conduct interviews or surveys.

Define

Before you start to design your vertical garden, you need to define the criteria that you will use to test the success of your vertical garden in achieving your goal.

Define your version of the problem

Rewrite the problem so that you describe the group you are helping, the problem they are experiencing and why it is important. Use the following phrase as a guide:

'How can we help (the group) to solve (the problem) so that (the reason)?'

Determine the criteria

1 What is the total area of the 100 m × 100 m plot of land? (Remember to use the correct units.)

2 If the plants are planted 25 cm apart in a 100 m row, and the rows are placed 1 m apart, how many plants could be planted in the plot of land? HINT: Draw the plot of land to make sure you reach maximum capacity.

3 What criteria will you use to measure the success of your solution or design? How will you measure how much the end-users have been helped?

Ideate

Once you know who you're designing for, and you know what the criteria are, it's time to get creative!

As a group, brainstorm ways the problem can be solved. Remember that there are no bad ideas at this stage. One silly thought could lead to a genius innovation!

Once you have many possible solutions, it is time to sort them by possibility. Select three to five ideas that are possible. Research whether these ideas have already been produced by someone else. If they are already on the market, can you make a better version?

Build

Draw your top two vertical garden designs. Label each part of the designs. Include the materials that will be used for their construction.

Include in the designs:

a the total surface area available for plant growth

b a description of how food production will be increased c a description of how the design (inputs and waste) will impact the local ecosystem

d a description of how the workers will access all areas of the design to tend the plants

e at least one advantage and disadvantage of each design.

Select one of the designs to take to the building and testing stage.

Build the prototype

You will need to build at least three versions of your vertical garden design prototype. The first prototype garden will be tested for effectiveness. The second prototype will be used to survey the group you are helping. The third prototype will be used for the presentation. The prototype may be full size, or it may be a scale model (10 cm represents 1 m). Use the following questions as a guideline for your prototype:

- What materials will you use?
- What material will you use to represent the plants?
- How will you represent the height, width and angle of the finished prototype?

Test

Prototype 1

Use the scientific method to design an experiment that will test the effectiveness and strength of your first vertical garden prototype. You will test the prototype more than once, to compare results, so you will need to control your variables between tests. What criteria will you use to determine the success of your prototype? Conduct your tests and record your results.

Prototype 2

If your prototype will be used to help market gardeners, then you will need to generate a survey to test whether the prototype is appropriate for their use. (How would they use it? Would they consider buying it?)

If your prototype will be used to help another group, or native plants and animals, you will need to consider how you could test the impact it will have. (Will the prototype affect normal behaviours? How will the prototype affect the soil or waterways?)

Prototype 3

Use the information you have obtained from testing the first two versions to adapt your last prototype to be more effective and usable for the group you are helping. You may want to use the first two prototypes to demonstrate how the design has been improved.

Communicate

Present your vertical garden design to the class as though you are trying to get your peers to invest in it. Describe the criteria and testing used to measure the effectiveness of your vertical garden design.

In your presentation, you will need to:

- explain why we need to be more efficient with food production
- describe the key features of your design and how they improve or solve the problem of food shortages
- show a labelled, to-scale diagram of your prototype
- describe how the ecosystem will be affected by the installation of the prototype
- explain the relevant scientific principles that support your designed solution (e.g. water cycle, photosynthesis, nitrogen/carbon cycle)
- quantify the increase in food production that your design allows; present calculations to justify your claim
- present a calculation for the estimated cost of producing a full-size model of your design
- explain the implications of your design at a state or national level, by comparing the benefits and costs.

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This video will help you to better understand each phase of the design cycle.

How to manage your project
This 'how-to' video will help you to manage your time throughout the design cycle.

How to pitch your idea
This 'how-to' video will help you with the 'Communicate' phase of your project.

[STEAM project 2]

How can we harness technology so that we can live healthier lives?

A disorder or disease is a condition that affects the normal functioning of the body. Different disorders and diseases can affect many parts of the body. They can be caused by infectious agents such as bacteria or viruses that spread from person to person. Some disorders or diseases are inherited. Environmental factors (such as pollution or diet) can also have an impact on the development of disorders or diseases.

Heart disease, a non-infectious disease, is the leading cause of death globally. Mental health disorders, such as depression, bipolar disorder and dementia, also affect many people around the world.

Disorders and disease affect both high-income and low-income countries, but there are large differences in the ability of different healthcare systems to provide adequate care for people. The need for low-cost health care has led many researchers to investigate how technology can be used to help people live healthier lives.

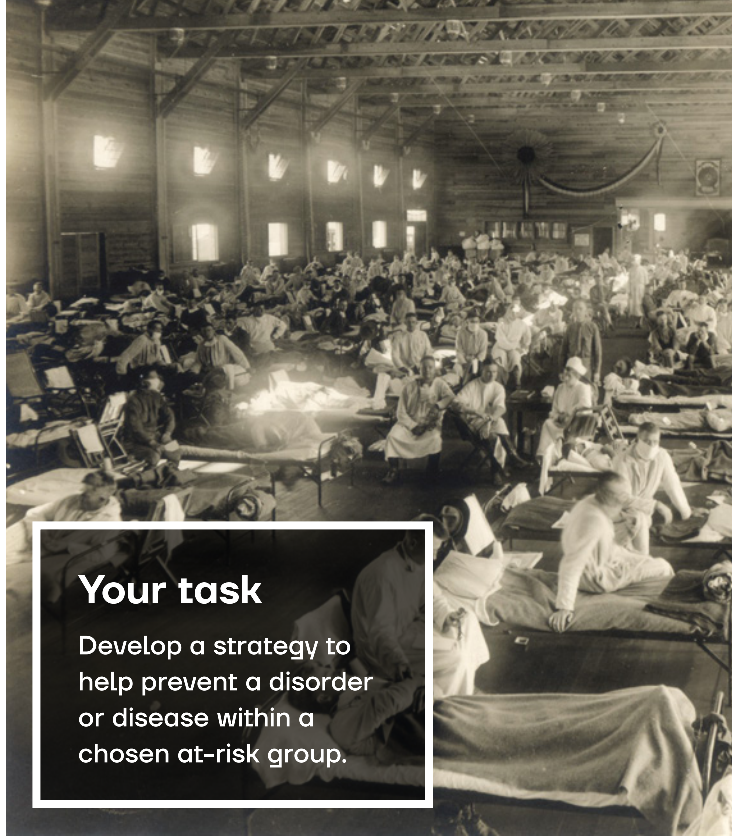

Figure 1 During the 1918 flu pandemic (sometimes called the Spanish flu), an estimated 500 million people, or a third of the world's population, were infected with the virus.

Prevention of disorders and disease

There are many disorders and diseases that can be prevented through simple, low-cost interventions. Below are a few examples.

- Wearing a helmet or a seat belt has been shown to decrease the risk of brain injury from a road accident. In Vietnam, when wearing a helmet was made mandatory for motorcycle riders, it resulted in a 16 per cent decrease in head injuries.
- The use of mosquito nets can help to prevent malaria, a disease that can lead to life-long neurological impairment, such as epilepsy in children if they have a severe infection.

Figure 2 Healthcare workers wear personal protective equipment (PPE) to prevent the spread of infectious disease.

- Providing vaccinations for viruses such as polio and meningitis can also prevent neurological conditions.
- Promoting a healthy lifestyle and educating the population about the importance of diet can reduce the prevalence of stroke. In Japan, campaigns and treatment for high blood

pressure have reduced the rate of strokes by 70 per cent.

- Personal protective equipment (PPE) is used to protect people from catching infectious diseases, such as COVID-19.

HUMANITIES

In Economics and Business this year, you will learn about how health services are provided in Australia. In Geography, you will study how people are interconnected through travel, technology and trade. These connections affect where and how people access the services they need. In History, you will examine the experiences of different groups during the Industrial Revolution, and the reforms made to improve living standards.

To complete this task successfully, you will need to research the demographics of your local area, and the location and accessibility of health services. You should also consider the economic performance of your area to determine what type of preventative strategy would be most successful for your at-risk group.

You will find more information on this in Chapter 14 ‘Understanding the economy’, Chapter 4 ‘An interconnected world’ and Chapter 9 ‘The Industrial Revolution and the movement of peoples’ of *Oxford Humanities and Social Sciences 9 Australian Curriculum*.

MATHS

In Maths this year, you will extend your skills in representing and interpreting data. You will consider media reports that use statistics and collect secondary data to investigate social issues. You will relate real-world data to probabilities of events, and compare data sets using summary statistics and different graphical displays. You will evaluate and represent data, both with and without digital technology.

To complete this task successfully, you will need to find data to quantify the problem, work out how much your strategy will cost, and calculate a quantitative, evidence-based estimate of the possible benefits of your strategy. You will need skills in dealing with ratios, proportions and percentages to consider the situation at local, national and international scales.

You will find help for applying these maths skills in Chapter 7 ‘Statistics’ of *Oxford Maths 9 Australian Curriculum*.

SCIENCE

In Science this year, you will learn about how the body coordinates and regulates its internal systems so that it can respond to changes. When things change in the environment (such as the emergence of a disease-causing agent), or a part of the body fails, the normal functioning of the body is interrupted. The body needs to respond and attempt to return to a normal homeostatic state before permanent damage is caused.

To complete this task successfully, you will need to identify how the body's systems work together to maintain a functioning body. You should consider the type of disorder or disease that you will be fighting, and how it may cause changes in the body's normal function and response mechanisms.

You will find more information on this in Chapter 2 ‘Control and regulation’ of *Oxford Science 9 Australian Curriculum*.

[STEAM project 2]

The design cycle

To successfully complete this task, you will need to complete each of the phases of the design cycle.

Discover

When designing solutions to a problem, you need to know who you are helping and what they need. The people you are helping, who will use your design, are called your end-users.

Consider the following questions to help you empathise with your end-users:

- Who am I designing for? Is it the people directly affected by the disorder or disease, or do their families and carers need support too?
- What problems are they facing? Why are they facing them?
- What do they need? What do they not need?
- What does it feel like to face these problems? What words would you use to describe these feelings?

To answer these questions, you may need to investigate using different resources, or even conduct interviews or surveys.

Define

Before you start to design your solution to the problem, you need to define the parameters you are working towards.

Define your version of the problem

Rewrite the problem so that you describe the group you are helping, the problem they are experiencing and why it is important. Use the following phrase as a guide.

'How can we help (the group) to solve (the problem) so that (the reason)?'

Determine the criteria

1 Describe the type of life that the people you are helping lived before their lives were affected by the disorder or disease.
2 Describe how the people affected by the disease have needed to change their lives to cope with the effects of the disorder or disease.
3 Describe how you will know that you have made their lives better as a result of your prototype strategy.

Ideate

Once you know who you're designing for, and you know what the criteria are, it's time to get creative!

Outline the criteria or requirements your design must fulfil (i.e. usability, accessibility, cost).

Brainstorm at least one idea per person that fulfils the criteria.

Remember that there are no bad ideas at this stage. One silly thought could lead to a genius innovation!

Build

Each group member should draw an individually designed solution. Label each part of the design. Include the material that will be used for its construction.

Include in the individual designs:

a a detailed diagram of the design
b a description of why it is needed by the individual or group

c a description of any similar designs that are already available to buy
d an outline of why your idea or design is better than others that can be purchased.

Present your design to your group.

Build the prototype

Choose one design and build two or three prototypes.

Use the following questions as a guideline for your prototype.

- What materials or technology will you need to build or represent your prototype design?
- What skills will you need to construct your prototype design?
- How will you make sure your prototype design is able to be used by the people who need it?
- How will you describe the way the prototype design will work?

Test

Prototype 1

Use the scientific method to design an experiment that will test the effectiveness and strength of your first prototype. You will test the prototype more than once, to compare results, so you will need to control your variables between tests.

What criteria will you use to determine the success of your prototype?

Conduct your tests and record your results in an appropriate table.

Prototype 2

If your prototype will be used to help individuals with the disorder or disease, then you will need to generate a survey to test whether the prototype is appropriate for their use. (How would they use it? Would it make their life easier or harder? Would they consider buying it? How much would they be willing to pay to access the design?)

Prototype 3

Your last prototype should be adapted using the information gathered from testing the first two versions to make it more effective and usable for the group you are helping. You may want to use the first two prototypes as a demonstration of how the design has been improved over time.

Communicate

Present your design to the class as though you are trying to get your peers to invest in your design.

In your presentation, you will need to:

- outline the relevant disorder or disease and how it affects individuals, as well as society as a whole
- create a working model, or a detailed series of diagrams, with a description of how it will be used by an individual and group
- explain how you changed your design as a result of testing or feedback
- describe how the design will improve the life of an individual or group
- describe how many people need or will use the design
- describe how individuals will be able to access the design (will they need to purchase it or will it be publicly funded?)
- describe how the design will improve an individual's ability to contribute to society as a whole.

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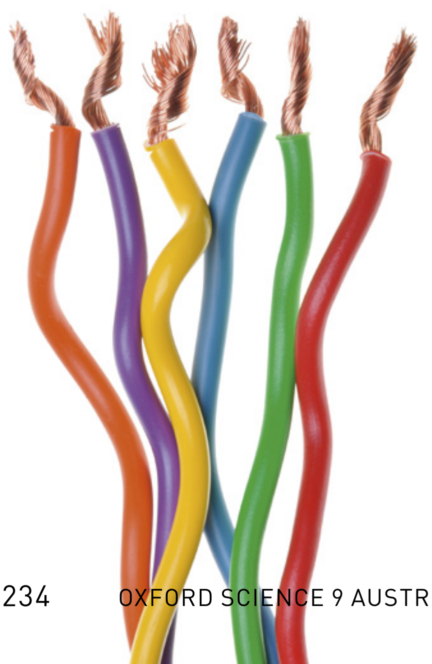
How to define a problem
This 'how-to' video will help you to narrow your ideas down and define a specific problem.

GLOSSARY



A

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

aerobic cellular respiration
a chemical reaction between glucose and oxygen to produce carbon dioxide, water and energy

allergy
an overreaction by the immune system in response to pollen, dust or other non-pathogens

alpha particle
a radioactive particle containing two protons and two neutrons; can be stopped by a piece of paper

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

anaphylaxis
a life-threatening overreaction by the immune system to a normally harmless substance

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

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

angle of refraction
the angle between a refracted ray and the normal (a line drawn at right angles to a refractive surface)

anther
the end part of a stamen (male part of a flower); contains pollen

antibody
a molecule produced by B cells that binds to a specific pathogen

atmosphere
the layer of gases surrounding the Earth

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

autonomic nervous system
the part of the nervous system that controls involuntary actions such as heartbeat, breathing and digestion

axon
the part of a neuron (nerve cell) that carries an electrical message away from the cell body to the synapse

B

B cell
an immune system cell that produces antibodies in response to pathogens

beta particle
a radioactive particle (high-speed electron or positron) with little mass; can be stopped by aluminium or tin foil

binary fission
a form of asexual reproduction used by bacteria; the splitting of a parent cell into two equal daughter cells

biodegradable
describes an object or a substance that can be broken down by bacteria, fungi or other living organisms

biodiversity
the variety of life; the different plants, animals and micro-organisms and the ecosystems they live in

biosphere
a layer around the Earth's surface that supports life; consists of the atmosphere, hydrosphere and lithosphere

C

carbon dating
a method of estimating the age of organic material, by comparing the amount of carbon-14 in the material with the amount in the atmosphere, knowing the rate at which carbon-14 decays over time

carbon sink
any feature of the environment that absorbs and/or stores carbon

carbon tax
a tax levied on the carbon content of fuels used by businesses or homes

carbon trading scheme
the process of allocating a set limit of carbon credits to businesses, which can then trade the credits

carpel
the female productive organ of a flower; includes the stigma, style and ovary

cell body
the main part of a cell that contains the nucleus/genetic material

cellular respiration
chemical reaction that transfers energy to cells

central nervous system
the brain and spinal cord

cervix
the narrow neck connecting the uterus and the vagina

circular economy
an economic system where materials are reused and recycled rather than used and disposed of

cognition
mental processes that are involved in acquiring, storing, manipulating and retrieving information

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

combustion reaction
a reaction between a fuel and oxygen that produces heat and water

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

concave
refers to a lens or mirror that is thinner in the centre than at the ends

conduction
the transfer of thermal energy from hot objects to cooler objects by direct contact with no movement of material

contraception
a way of preventing pregnancy

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

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

converge
(in relation to rays of light) to come together at a single point

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

correlated
when results in an experiment show that independent and dependent variables are related

critical angle
the angle of light that causes the reflected ray to move along the edge between two materials

cross-pollination
the exchange of pollen and ova between different plants of the same species

cryosphere
the frozen water in the hydrosphere

cultural burning
the practice of burning vegetation used by Traditional Custodians of Country to enhance the health of Country; informed by deep knowledge of and relationship to Country

D

dendrite
the part of a neuron (nerve cell) that receives a message and sends it to the cell body

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

desexing
a method of permanently preventing reproduction

dispersion
the separation of white light into its different colours

diverge
(in relation to rays of light) to move away from each other

dry cell
an object, such as a torch battery, that uses a chemical reaction to produce electrical energy

E

electric circuit
a closed pathway that conducts electrons in the form of electrical energy

electrical conductor
a material through which charged particles are able to move

electrical energy
the energy that results in the movement of elections through a conductor towards a positive charge

electrical insulator
a material that does not allow the movement of charged particles

electron
a negatively charged particle in the nucleus of an atom

electrostatic charge
an electrical charge that is trapped in an object such as a balloon

endocrine system
a collection of glands that make and release hormones

endometrium
the lining of the uterus

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

enhanced greenhouse effect
an increase in carbon dioxide and other heat-capturing gases in the atmosphere, resulting in increased warming of the Earth

epididymis
a coiled tube behind the testes that carries sperm to the vas deferens

external fertilisation
when the egg and sperm meet outside the bodies of the parents

extrapolation
estimating unknown values from trends in known data

F

fallopian tubes
tubes that connect the ovaries to the uterus

fertilisation
the process where two gametes (sex cells) fuse to produce a single cell

fetus
an unborn animal or human after the embryo stage; in humans this is after 8 weeks of development

filter
a transparent material that allows only one colour of light to pass through

focal length
the distance between the centre of a lens and the focus

focus
the point where rays of light cross

fragmentation
asexual reproduction that occurs when a new organism grows from a fragment of the parent

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

fuel
a substance that undergoes a chemical reaction producing large amounts of energy

fuse
a switch or wire that stops the flow of current if it starts moving too fast

G

gamete
a sex cell; in humans, the sperm and egg cells

gamma rays
high-energy electromagnetic rays released as a part of radioactive decay; can be stopped by lead

gestation
the length of time between fertilisation and birth

group
a vertical list of elements in the periodic table that have characteristics in common

H

half-life
the time it takes the radioactivity in a substance to decrease by half

hermaphrodite
an organism that has both male and female reproductive systems

hertz
the unit used to measure frequency

homeostasis
the process by which the body detects and responds to stimuli to ensure a stable internal state is maintained

hormone
a chemical messenger that travels through blood vessels to target cells

hydrocarbon
a molecule that contains only carbon and hydrogen atoms

hydrosphere
all the solid, liquid and gaseous waters on Earth that support life

hyperglycaemia
when there are high levels of glucose in the blood, which can occur when the body has too little insulin

hypoglycaemia
when there are low levels of glucose in the blood, which can occur when the body has too much insulin

hypothermia
the condition of having an abnormal, potentially dangerous, low body temperature

I

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

immune
able to fight an infection as a result of prior exposure

immune system
a system of organs and structures that protect an organism against disease

inbreeding
breeding of animals that are related, increasing the chances of genetic abnormalities appearing

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

insulator
a substance that prevents the movement of thermal or electrical energy

internal fertilisation
when the sperm fertilises the egg inside the body of an organism

interneuron
a nerve cell that links sensory and motor neurons; also known as a connector neuron

isotope
an atom of a particular element that has more or fewer neutrons in its nucleus than another atom of the same element

K

K-strategist
organisms living in stable environments who breed carefully

L

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

lens
a curved piece of transparent material

lithosphere
the outermost later of Earth, consisting of the upper mantle and crust

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

M

mass number
a number that represents the total number of protons and neutrons in the centre of an atom

matter
anything that has space and volume; matter is made up of atoms

medium
a substance or material through which light can move

memory cell
an immune system cell produced in response to an infection; retains the memory of how to fight the pathogen

menstruation
also known as a period; the process of the endometrial lining of the uterus breaking down and leaving the vagina

mineral
a naturally occuring element or compound

motor neuron
a nerve cell that carries a message from the central nervous system to a muscle cell

myelin sheath
a fatty layer that covers the axon of a nerve cell

N

natural greenhouse effect
the natural warming of the Earth due to water vapour and other gases being present in small amounts in the atmosphere and affecting the Earth's radiation balance

negative feedback mechanism
a regulatory loop in which the stimulus causes a response that acts in the opposite direction to whatever is being regulated

neuron
a nerve cell

neurotransmitter
a chemical messenger that crosses the synapse between the axon of one neuron and the dendrite of another neuron

neutron
a neutral (no charge) subatomic particle in the nucleus of an atom

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

nucleus
1. in biology: a membrane-bound structure in cells that contains most of the cell's genetic material; 2. in chemistry: the centre of an atom, containing protons (positive charge) and neutrons (no charge)

O

ocean acidification
the production of carbonic acid in the ocean due to the absorption of carbon dioxide

oestrogen
a reproductive hormone in females

offspring
an organism's young, or child

opaque
not allowing light to pass through

optic fibre
a thin fibre of glass or plastic that carries information/data in the form of light

ore
a rock that contains a high percentage of one type of mineral

ovary
the female organ that produces eggs

oviduct
the tube through which eggs travel from the ovary

ovulation
the part of the menstrual cycle when an egg is released from the ovary

ovum
the reproductive egg

P

parallel
the positioning of loads (e.g. lights) in an electric circuit so they are connected to the battery separately; they are in parallel to one another

parthenogenesis
asexual reproduction where a female fertilises her own eggs

pathogen
a microbe that can cause disease

period
(in chemistry) a horizontal list of elements in the periodic table

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

peripheral nervous system
all the neurons (nerve cells) that function outside the brain and spinal cord

permafrost
permanently frozen ground

phagocyte
an immune system cell that surrounds, absorbs and destroys pathogens

photosynthesis
a chemical process used by plants to make glucose and oxygen from carbon dioxide, sunlight and water

placenta
the organ that connects the developing fetus to its mother

pollination
fertilisation of gametes in plants

potential difference
voltage; the difference in the electrical potential energy carried by charged particles at different points in a circuit

primary colours of light
the three colours of light (red, blue and green), which can be mixed to create white light

product
a substance obtained at the end of a chemical reaction; written on the right side of a chemical equation

prostate gland
a walnut-sized structure surrounding the neck of the male bladder that blocks the flow of urine so sperm can move along the urethra

proton
a positively charged subatomic particle in the nucleus of an atom

R

r-strategist
organisms living in unstable environments who breed rapidly

radioactive decay
the conversion of a radioactive isotope into its stable form, releasing energy in the form of radiation

radionuclide
a radioactive isotope

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

reactant
a substance used at the beginning of a chemical reaction; written on the left side of a chemical equation

receptor
a structure that detects a stimulus or change in the normal functioning of the body

reflex
an involuntary movement in response to a stimulus

refracted ray
a ray of light that has bent as a result of speeding up or slowing down when it moves into a more or less dense medium

refraction
the bending of light as a result of speeding up or slowing down when moving into a medium of different density

refractive index
a measure of the bending of light as it passes from one medium to another

relative atomic mass
the average mass of an element, including the mass and prevalence of its different isotopes

reproducible
the ability to repeat and replicate a test exactly

resistance
a measure of how difficult it is for the charged particles in an electric circuit to move

rheumatoid arthritis
an autoimmune disease in which the immune system attacks the joints of the body

S

sample size
the number of subjects being tested or used in an experiment

scrotum
a sac-like structure that contains the testes

secondary colours of light
the colours of light (magenta, cyan and yellow) that result from the mixing of two primary colours of light

self-pollination
when both gametes come from the same plant

semiconductor
a material that conducts electrical energy in one form and insulates against electrical energy in another form

seminal vesicles
a pair of small pouch-like structures that provide a sugary fluid that assists sperm to travel along the vas deferens

sensory neuron
a nerve cell that carries a message from a receptor to the central nervous system

series
the positioning of loads (e.g. lights) side by side in an electric circuit so that the electrical energy passes through one load at a time

sexually dimorphic
describes species in which the male and female organisms look structurally different

short circuit
when electrical current flows along a different path from the one that was intended

somatic nervous system
the part of the nervous system that controls the muscles attached to the skeletal system

sonar
the detection of the location of objects through the use of soundwaves

spore
a tiny reproductive structure that, unlike a gamete, does not need to fuse with another cell to form a new organism

stigma
the male part of a plant, consisting of a filament supporting an anther

stimulus
any information that the body receives that causes it to respond

subatomic particle
a particle that is smaller than an atom

synapse
a small gap between two neurons that must be crossed by neurotransmitters

T

T cell
an immune system cell that recognises and kills pathogens

target cell
a cell that has a receptor that matches a specific hormone

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

testis
the male reproductive organ that produces sperm (plural: testes)

testosterone
a male hormone involved in the reproductive system

thermal conductor
a material that allows thermal energy to flow through

thermal insulator
a material that prevents or slows down the transfer of thermal energy

Thomson plum pudding model
an early model of the atom in which the positively charged nucleus has negatively charged electrons scattered through it, like a plum pudding

total internal reflection
the complete reflection of a light ray when it passes from a more dense to a less dense material at a large angle; the ray is reflected back into the dense medium

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

transmit
to allow light to pass through

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

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

type 1 diabetes
an autoimmune disease in which the immune system attacks the insulin-producing cells in the pancreas

U

uncertainty
a quantitative measurement of variability in the data

uterus
an organ in the female reproductive system; where the fetus develops

V

vaccination
an injection of an inactive or artificial pathogen that results in the individual becoming immune to a particular disease

vagina
a female reproductive organ; a muscular tube connecting the outside of the female body to the cervix

valid
where a test investigates what it sets out to investigate

van de Graaff generator
a machine that produces an electrostatic charge

vas deferens
the tube through which sperm travel from the epididymis to the prostate

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

vegetative reproduction
a type of asexual reproduction where part of a plant breaks off, forming a new organism with no need for seeds or spores; similar to fragmentation

virtual focus
the point at which a virtual image appears

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

visible spectrum
the variety of colours of wavelengths of light that can be seen by the human eye

voltage
potential difference; the difference in the electrical potential energy carried by charged particles at different points in a circuit

W

wavelength
the distance between two crests or troughs of a wave

wet cell
an object, such as a car battery, that uses a chemical reaction to produce electrical energy

white blood cell
an immune system cell that destroys pathogens

Z

zygote
a fertilised egg

INDEX

D

E

F

G

Seventy per cent of Earth's surface is made up of water, making our planet appear blue when viewed from space. This vast amount of water can be found in the form of a liquid, vapour or solid (glaciers, snow and icebergs) and it is home to many plant and animal species. This image shows an ice cave. Frozen forms of water such as this are very important in regulating the climate on Earth and the volume of nutrients in the oceans. Water, in all its forms, is essential for life on Earth.

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