GRAEME LOFTS | MERRIN J. EVERGREEN

JACARANDA SCIENCE QUEST 9

VICTORIAN CURRICULUM | SECOND EDITION

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GRAEME LOFTS | MERRIN J. EVERGREEN

CONTRIBUTING AUTHORS

Nicole Cox | Vicki Duffy | John E. Morley

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All activities have been written with the safety of both teacher and student in mind. Some, however, involve physical activity or the use of equipment or tools. All due care should be taken when performing such activities. Neither the publisher nor the authors can accept responsibility for any injury that may be sustained when completing activities described in this textbook.

This suite of print and digital resources may contain images of, or references to, members of Aboriginal and Torres Strait Islander communities who are, or may be, deceased. These images and references have been included to help Australian students from all cultural backgrounds develop a better understanding of Aboriginal and Torres Strait Islander peoples' history, culture and lived experience.

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PREFACE

To the science student

Science is much more than a body of knowledge. It is a way of thinking and learning, which we refer to as Science Inquiry. Science helps you understand the world around you: why the sun rises and sets every day, why it rains, how you see and hear, why you need a skeleton and how to treat water to make it safe to drink. You can't escape the benefits of science. Whenever you turn on a light, eat food, watch television or flush the toilet, you are using the products of scientific knowledge and inquiry.

Global pandemics, climate change, overpopulation, famine, pollution, resource shortages, the potential use of biological and nuclear weapons, and issues associated with genetic engineering currently challenge the world as we know it. Possible solutions to some of these challenges may be found by applying scientific knowledge to develop new technologies and creative ways of rethinking the problems. It's not just scientists who solve these problems; people with an understanding of science, like you, can influence the future. It can be as simple as using a recycling bin or saving energy and water in your home.

Science inquiry involves both identifying problems that need to be solved, and planning and conducting investigations. It involves collecting, processing and interpreting evidence so that useful conclusions can be reached. Science inquiry could involve, for example, investigating whether life is possible on other planets, discovering how to make food crops grow with less water, finding out how to swim faster, developing a vaccine for COVID-19 and even finding a cure for cancer. Science inquiry usually involves working with a team. The outcomes of science inquiry should be shared with other scientists and the community at large.

You live in a time in which the growth of scientific knowledge and technological development is occurring faster than ever before. A consequence of this is that learning how to learn has become just as important as learning itself. *Science Quest* has been designed with this in mind, taking you on a quest for both scientific knowledge and inquiry.

To the science teacher

This edition of the *Science Quest* VC series has been developed to enhance the already comprehensive suite of engaging and innovative resources tailored to the Victorian Curriculum of the previous edition. It provides both activities that focus on seven **general capabilities** (literacy, numeracy, ICT competence, critical and creative thinking, ethical behaviour, personal and social competence, and intercultural understanding) and **differentiated learning**. The history and culture of Aboriginal and Torres Strait Islanders, Australia's engagement with Asia, and sustainability have been embedded with the general capabilities where relevant and appropriate.

Science Quest interweaves **Science understanding** with **Science as a human endeavour** and **Science inquiry skills** under the umbrella of six **Overarching ideas** that 'represent key aspects of a scientific view of the world and bridge knowledge and understanding across the disciplines of science'.

Science Quest provides the basis for the development of a course of study based on the Victorian Curriculum. This new edition incorporates practical activities and resources that provide tools for science inquiry in remote learning settings as well as in the classroom.

We have attempted to make the *Science Quest* VC series a valuable asset for teachers, and interesting and relevant to the students who are using it. *Science Quest* VC comes complete with online support for students, including answers to questions, interactivities to help students investigate concepts, and video eLessons featuring real scientists and real-world science.

Exclusively for teachers, the online *Science Quest* teacher resources provide teaching advice and suggested additional resources, testmaker questions with assessment rubrics, and worksheets and answers.

Graeme Lofts and *Merrin J. Evergreen*

ABOUT THE AUTHORS

AUTHORS

Dr Merrin J. Evergreen

Merrin J. Evergreen has been awarded academic qualifications from five different Australian universities, and was awarded Monash University's Jeff Northfield Memorial Award for Excellence in Teacher Research.

Merrin loves the excitement and fun of learning, and with thirty years of experience as a science and biology teacher (both Victorian Certificate of Education and International Baccalaureate), Merrin endeavours to share and transfer both her passion and understanding of teaching and learning into each new and evolving edition. Her quest continues to be that of inspiring others with the excitement of learning and understanding more about ourselves, our world, and our place within it.

Graeme Lofts

Graeme Lofts has taught physics, science and mathematics at both government and independent schools in Victoria for more than twenty-three years. He has also lectured in Science Education at the University of Melbourne and RMIT University. During his teaching career Graeme was awarded an International Teaching Fellowship, the BHP Science Teacher Award and an STAV Fellowship 'for major contributions to the Science Teachers' Association of Victoria'.

Graeme remains passionate about science education and is keen to see *Science Quest* continue to improve and adapt to rapidly advancing teaching and learning technology. He is determined that it must remain relevant and address important issues of concern for the students and teachers using it.

CONTRIBUTING AUTHORS

Nicole Cox

Nicole Cox has a Master of Science in Geology. Her passion for exploring landscapes and learning how the Earth works has led her on many global adventures, which inspired her to share that passion to others through teaching. Nicole taught geologic and environmental subjects at a university level for 11 years and is currently an independent consultant for both geoscience education and the resource industry.

Vicki Duffy

Vicki Duffy has a Bachelor of Science (Honours in Biology and Environmental studies) and Diploma of Education. Recently retired, she has over 35 years of experience in the classroom in both the public and private education sectors. She has kept abreast of all new teaching styles and developments in the science curriculum and continues to offer scientific support and guidance to local schools and community groups. Her passion for teaching has been passed on to her children who have become inspirational teachers.

John E. Morley

John E. Morley has a Bachelor of Science (Joint Honours in Physics with Astrophysics) and a PhD in X-ray Astrophysics. During his time in research John discovered an interest in education and retrained as a teacher. In 2015, after 18 years of teaching in the UK, John and his family moved to Australia. He is currently the Head of Science at Ballarat Clarendon College, where he teaches VCE Physics and science across a range of ages. John has also been a VCAA assessor for VCE Physics. John is a strong advocate for recruiting more girls and other under-represented groups to the study of senior Physics.

Neale Taylor

Neale Taylor has a Bachelor of Science (Chemistry and Pure Mathematics) and a Diploma of Education, with over 20 years of secondary teaching experience, including two years of teaching the Diploma of Education, Chemistry at RMIT. Neale has authored both junior and senior Chemistry texts and has written and coordinated the VCE Chemistry Trial exams for The Centre for Strategic Education. Having previously enjoyed 14 years as Science publisher at Jacaranda, Neale has returned to authoring to share his enthusiasm and experience of science with the next generation of students.

Nicole Webster

Nicole Webster has a Bachelor of Science (Honours), a PhD in Immunology and a Masters of Teaching, from the University of Melbourne. She was formerly a medical research scientist and an American Foundation of AIDS Research (amfAR) Fellow, completing three post-doctoral positions over 16 years. Nicole draws on her love of the biological sciences, extensive industry experience and passion for teaching to make complex scientific concepts more accessible to all students. Nicole is currently the Head of Talent and Potential, the gifted learning program, at Overnewton Anglican Community College, and a passionate teacher of science and VCE Biology.

Ben Williams

Ben Williams is a former research scientist with a PhD in cancer vaccines. After completing a Graduate Diploma of Teaching he has taught in both the government and independent sectors, and is currently International Baccalaureate Chemistry Lead, and VCE Chemistry and Science teacher at Methodist Ladies' College in Kew. Ben's educational interests centre around embedding clear and rigorous scientific practice in syllabus materials, to prepare students for both further studies in science and to develop their critical analysis skills more broadly.

ABOUT THIS TITLE

New features!

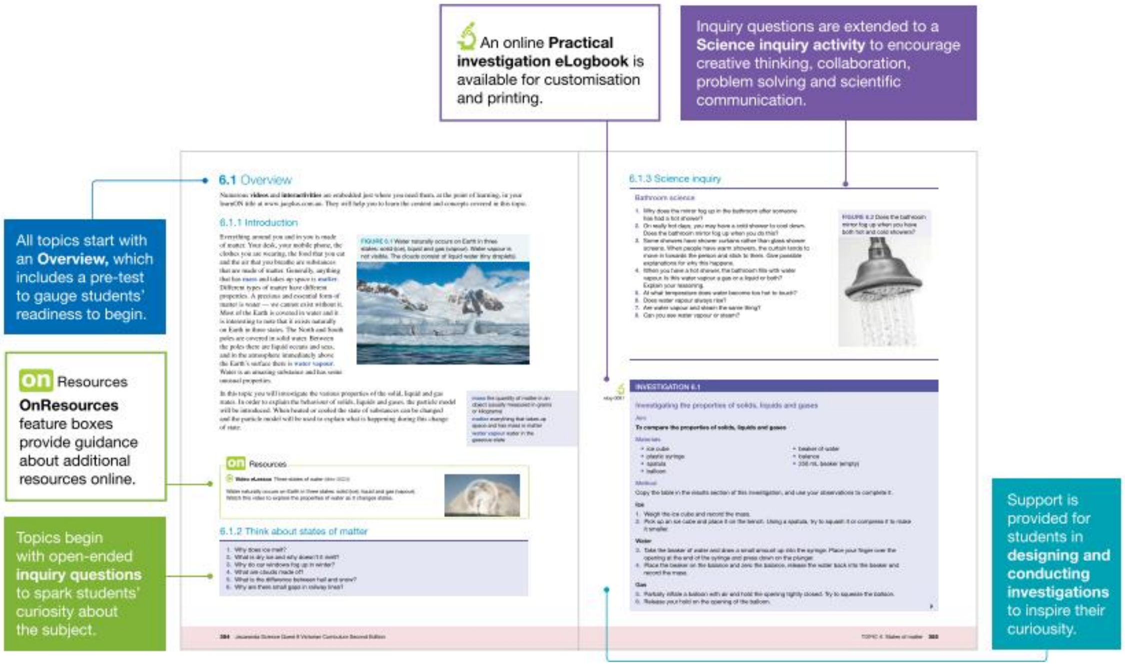
Jacaranda Science Quest Victorian Curriculum Second Edition has been completely revised and updated to help teachers and students navigate the Victorian Curriculum syllabus. The *Jacaranda Science Quest* series is designed to enrich the learning experience and improve learning outcomes for all students. The series is available across a number of digital formats: learnON, eBookPLUS, eGuidePLUS, PDF and iPad app.

DIGITAL					
learnON	**eBookPLUS**	**eGuidePLUS**	**PDF**	**iPad app**	**Print**
An immersive, interactive and flexible online learning course	An electronic version of the student text, with digital resources	Everything in the eBookPLUS plus additional resources designed for teachers	Downloadable PDFs directly from your Jacaranda bookshelf	Access trusted Jacaranda content both online and offline	Printed textbook with free digital access code inside

Teaching Science inquiry skills, sparking curiosity

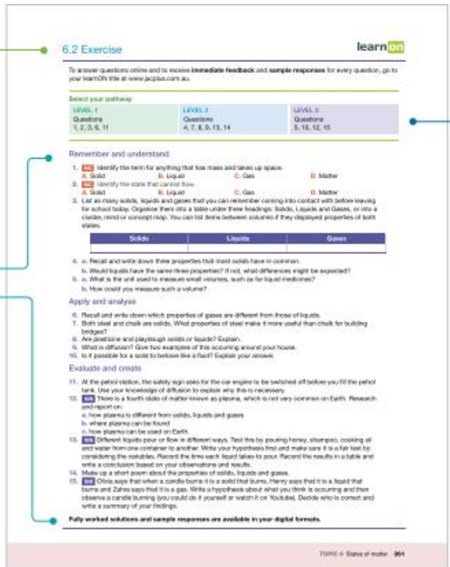
Science is an engaging, dynamic, inquiry-based subject that provides students with the opportunity to understand the world around them. The understanding of science involves more than understanding concepts; it also involves learning how to inquire, communicate and investigate scientifically. Science inquiry skills (SIS) are integrated throughout, through explicitly targeted SkillBuilders and a dedicated, stand-alone science inquiry topic that introduces students to the key components of predicting, conducting, designing, communicating and evaluating scientific investigations. This topic has been specifically tailored for each year level in content and complexity, to show the progression of inquiry skills throughout students' studies of science. Throughout the topics, students will find links to SIS alongside exercises and activities.

This suite of resources is designed to allow for differentiation, flexible teaching and multiple entry and exit points so teachers can teach their class their way.



Exercise sets at the end of each subtopic allow students to check and apply their understanding.

Corrective feedback and sample responses are available online for every question.



Questions at 3 levels of difficulty provide differentiation while allowing all students to work on the same subtopic.

Level 1 Try these for initial understanding.

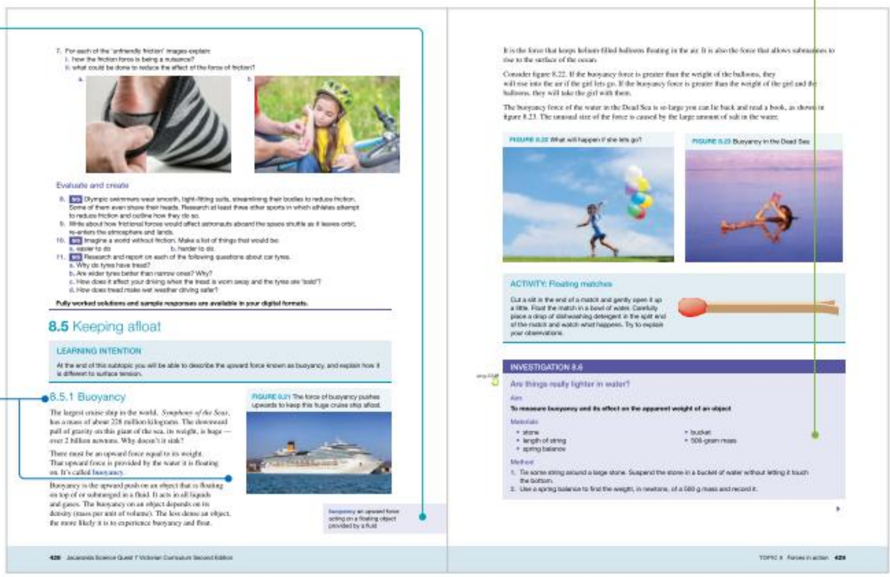
Level 2 Try these when you're feeling more confident.

Level 3 Try these when you're ready to try something harder.

Practical investigations throughout each topic provide students with opportunities to engage with science and develop an understanding of content and science skills.

Definitions are provided within the content to help students understand key terms; online, definitions are included as clickable pop-up notes.

Content is presented using **age-appropriate language** and a wide range of engaging interactivities, diagrams and images to support concept learning.

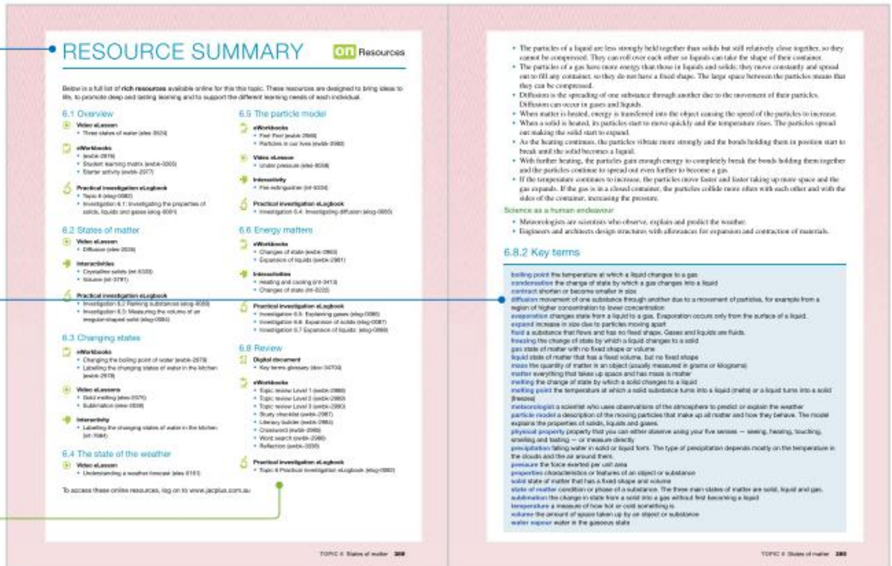


Resource summaries for each topic help teachers and students to find online resources easily and quickly.

A **range of questions** and a post-test are available online and in print to test students' understanding of the topic.

Summaries and key terms are available in every topic review.

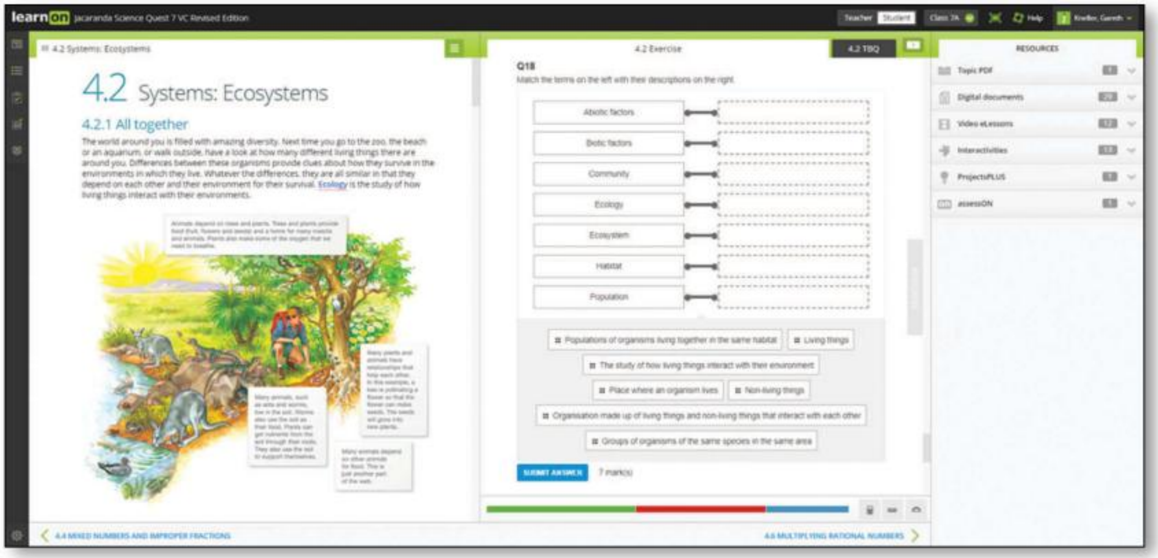
An online **eWorkbook** is available for customisation and printing. It contains numerous worksheets including a literacy builder, a student learning matrix and opportunities for reflection to encourage students to take ownership of their learning.



ACCESS ALL OF YOUR ONLINE RESOURCES

Using learnON

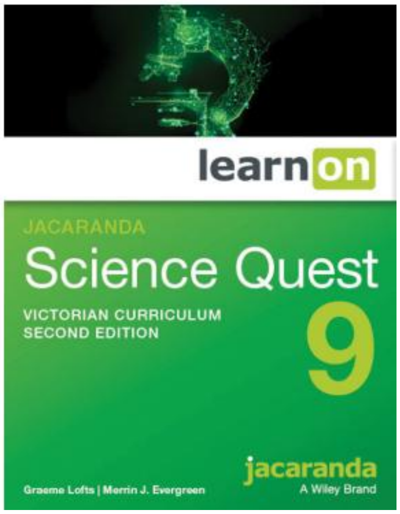
The *Jacaranda Science Quest Victorian Curriculum* series learnON resources provide an immersive digital learning platform that provides teachers with valuable insights into their students' learning and engagement. Hundreds of engaging videos and interactivities are embedded just where you need them — at the point of learning. learnON provides a deeper, richer and more meaningful teaching and learning experience for educators and their students in today's digital world, with important additional features that allow you to assign, mark and track student work. The platform can monitor and report progress in real time to give you immediate insights into student achievement. This helps you to easily isolate areas in which students (or groups of students) need additional support or extension.



The learnON platform gives you the control over your students' learning pathways.

Some of the many benefits of the learnON platform include:

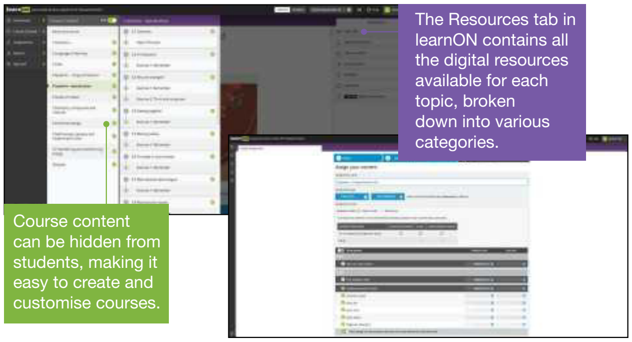
- online questions with a 1 : 1 correspondence to questions in print
- real-time immediate corrective feedback and fully worked solutions for every question to help students get unstuck
- a new side-by-side lesson view, enabling access to reading content and question sets on one screen
- hundreds of videos and interactivities to bring concepts to life
- customisable course content, giving teachers more flexibility to create their own course
- the ability to connect students and teachers in a class group
- the ability to separate a class into subgroups, making differentiation simpler
- dashboards to track progress
- immediate insight into student progress and performance using the Results page
- the ability to send important documents to the class
- formative and summative assessments.



Customise student learning

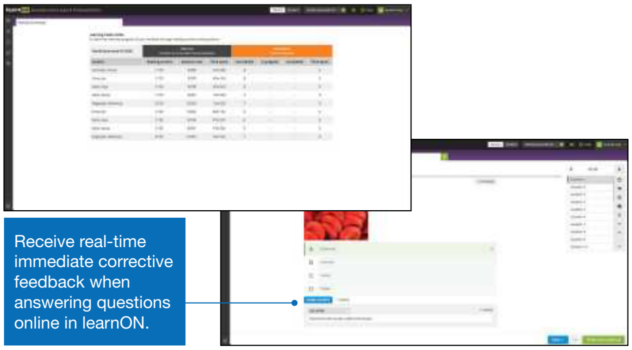
At Jacaranda, we understand that no-one knows your students' learning needs better than you. With learnON, you can tailor each task and assign it to individual students, create your own groups or assign to the whole class. You have complete control over assigning questions or tasks for each student, whether they are for practice or assessment, due dates and when students have access to results.

You also have the ability to hide specific parts of the reading content from student view, to allow for closed-book tests or to create your own pathway through the material for your class.



Track activity

The learnON platform provides real-time summaries of student activity. At a glance, you can see how long a student spends reading content pages, how many question-sets they have attempted and their progress with assessment tasks.

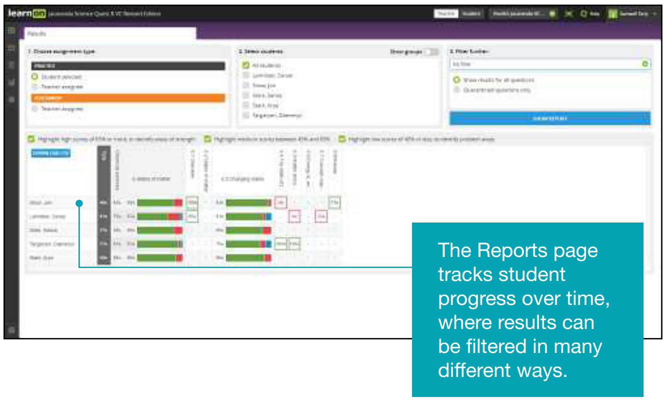


Provide meaningful feedback — quickly and easily

The learnON platform also provides an easy-to-navigate marking interface that allows you to see student responses, comment on and mark their work.

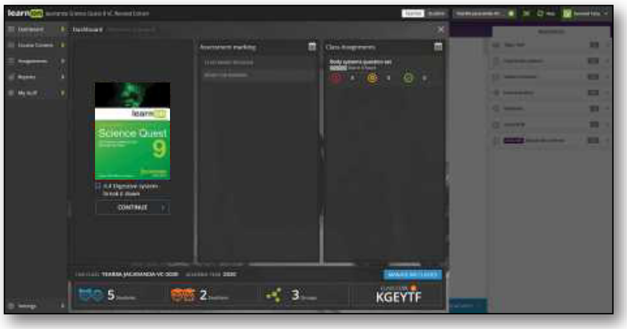
Gain deep insights into student performance

You also have access to detailed reports on student progress that allow you to filter results for specific skills or question types. With learnON, you can show students (or their parents or carers) their own assessment data in fine detail. You can filter their results to show their development with each proficiency strand, skill, topic or subtopic. Results are also colour-coded to help students understand their strengths and weaknesses at a glance.



Keep track of your 'to do' list

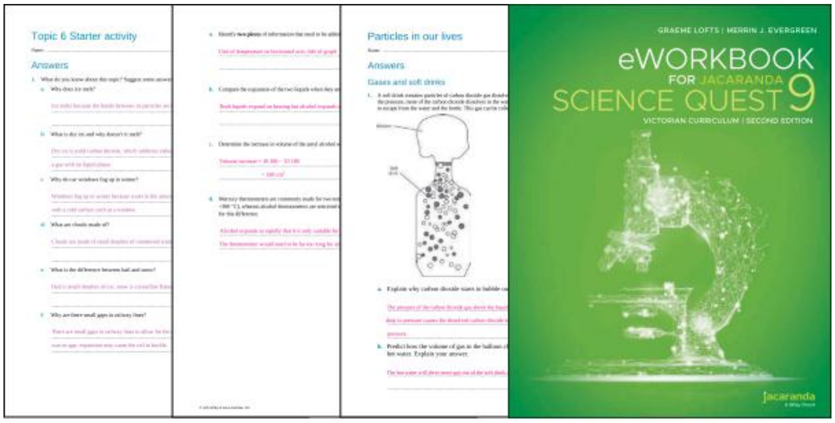
The learnON dashboard gives students and teachers a clear picture of their progress throughout the year. For teachers, it provides a visual summary of upcoming assessment deadlines, student submissions waiting to be marked and overdue tasks. For students, it providers reminders of due dates and notifications about the availability of feedback and marked tasks.



NEW in the *Jacaranda Science Quest* VC series

eWorkbook for Science Quest

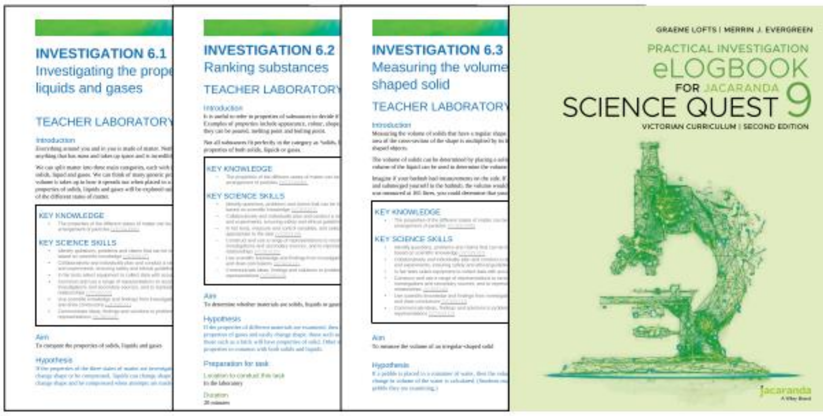
The **eWorkbook** is the perfect companion to the series, adding another layer of individualised learning opportunities for students, and catering for multiple entry and exit points in student learning. The eWorkbook also features fun and engaging activities for students of all abilities and offers a space for students to reflect on their own learning.



The new eWorkbook and eWorkbook solutions are available as downloadable PDFs or customisable Word documents in learnON.

Practical Investigation eLogbook for *Science Quest*

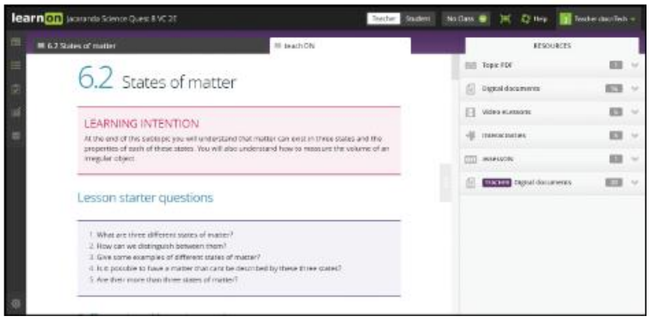
The **practical investigation eLogbook** ignites curiosity through science investigation work, with an extensive range of exciting and meaningful practical investigations. Aligned with the scientific method, students can develop rich science inquiry skills in conducting scientific investigations and communicating their findings, allowing them to truly think and act like scientists!



The practical investigation eLogbook is supported with an unrivalled teacher and laboratory guide, which provides suggestions for differentiation and alteration, risk assessments, expected practical results and exemplary responses.

teachON

teachON offers teachers time-saving support and inspiration, with ready-made lesson plans, practical teaching advice, differentiated work programs, extensive practical and lab support and customisable assessment. With access to the learnON platform, teachers also receive immediate insights into their students' performance and engagement.



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1 Investigating science

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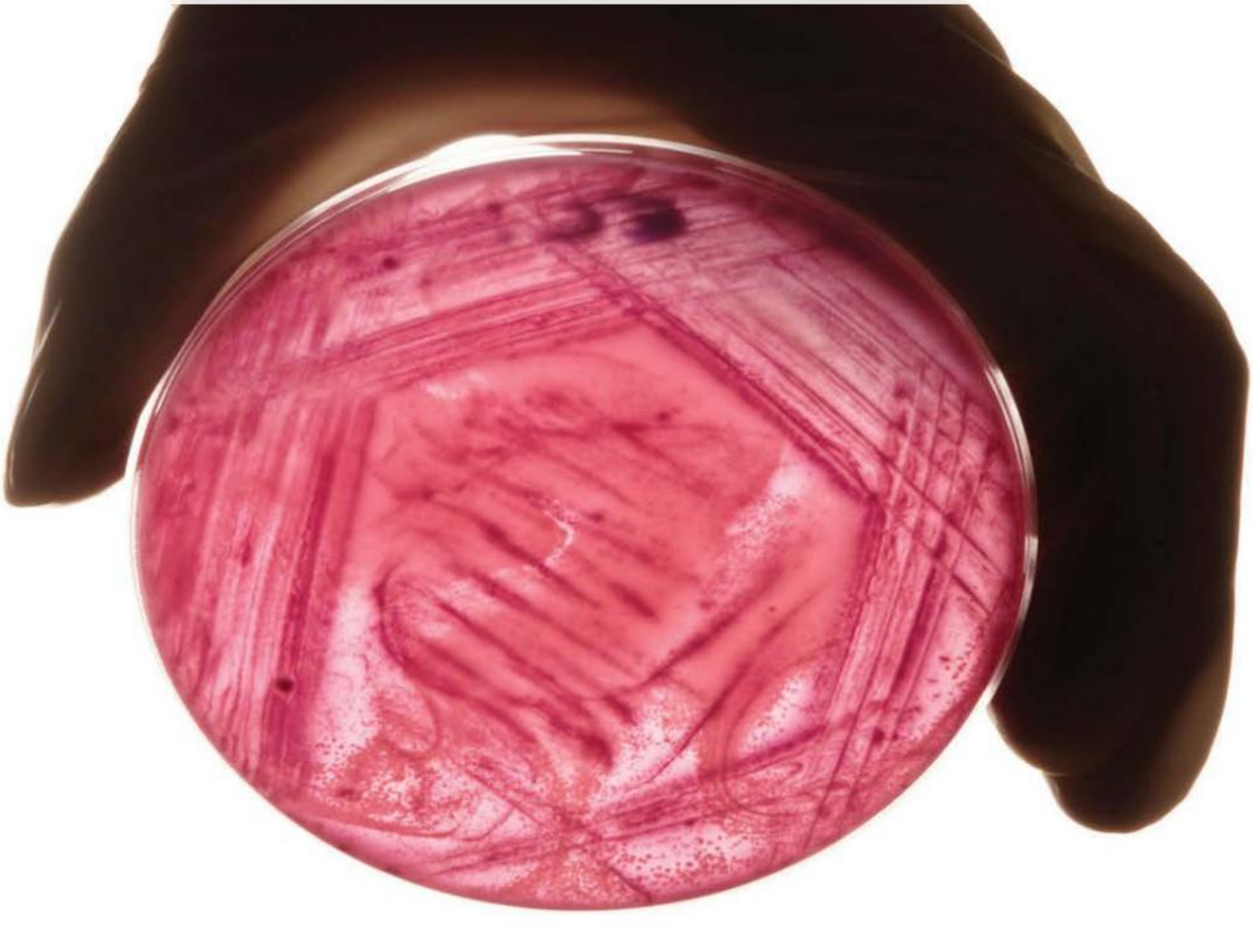


1.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

1.1.1 Introduction

You can find out a lot about science from books and the internet, but the best way to learn about it is to conduct your own scientific investigations. Whether you are a professional scientist, or a student at school or home, every investigation starts with a question — and a plan.

In this topic, and throughout your science studies this year, you will develop your skills as a scientist. While science inquiry starts with a question, to understand the natural world you need to make predictions (hypotheses) which you can test with experiments or observations. These tests need to be planned and carried out using the scientific method. This ensures your results are reliable and robust. If the results of your investigation do not support your hypothesis, it does not mean your investigation is a failure, it just means you need to change your hypothesis. Scientific knowledge is based on refining hypotheses and experimental methods, identifying relationships, evaluating claims, drawing conclusions and then communicating this knowledge appropriately.

FIGURE 1.1 The best way to understand science is to conduct your own investigations

on Resources

Video eLesson Australia's top scientists (eles-1079)

Watch this video eLesson to hear what inspires Australian scientists. The scientists in this video have been recognised as leaders in their fields of research and are elected fellows of the Australian Academy of Science.

Weblink The Australian Academy of Science

1.1.2 Think about science

1. How do all scientific investigations begin?
2. Which great medical discovery was helped along by a single teardrop?
3. Why planning is so important to a scientific investigation.
4. What is a controlled variable?
5. How can a spreadsheet save you time in a scientific investigation?
6. How does a data logger improve the gathering of data?
7. What scientific discovery do you think has changed the world the most?

1.1.3 Science inquiry

Scientific inquiry starts with a question

Questions, questions, questions! That's what scientific research is all about — questions such as:

- How old is the universe?
- Why did dinosaurs become extinct?
- What is the smallest particle inside an atom?
- How can the common cold be cured?

Every science investigation, whether it is conducted in a government research laboratory, a hospital, a museum or a space shuttle, begins with at least one question.

FIGURE 1.2 What is the best shape for a boomerang?

Although you are unlikely to even attempt to try to answer the preceding questions in your school science laboratory, there are many scientific questions that you can answer. Here are some examples.

- Does an audience affect the performance of an athlete?
- What is the best shape for a boomerang?
- Which type of soil do earthworms prefer?
- How do heating and cooling affect the way that rubber stretches?

What can I investigate?

1. In groups, brainstorm a list of questions that could be answered by doing an investigation in a school science laboratory. Record all the questions that are suggested even if they seem silly or difficult. The examples above might help you to think of some other ideas.
2. From your list, remove any questions that the group feels are not likely to be answered because of a lack of the right equipment. Keep a record of the questions that are removed for this reason to submit to your teacher. You may find that equipment you thought was unavailable can be obtained, or that the question can be answered with different equipment.
3. From your list, remove any questions that the group feels would be unsafe to try to answer, or that would be cruel to animals.
4. Submit the remaining questions to your teacher for discussion by the whole class.

on Resources

eWorkbooks Topic 1 eWorkbook (ewbk-5276)
Student learning matrix (ewbk-5278)
Starter activity (ewbk-5279)

learnon Access and answer an online Pre-test and receive **immediate corrective feedback** and **fully worked solutions** for all questions.

1.2 Scientists through the ages

LEARNING INTENTION

At the end of this subtopic you will be able to explain how scientific understanding is open to scrutiny and is refined over time, often relying on developments in technology and technological advances.

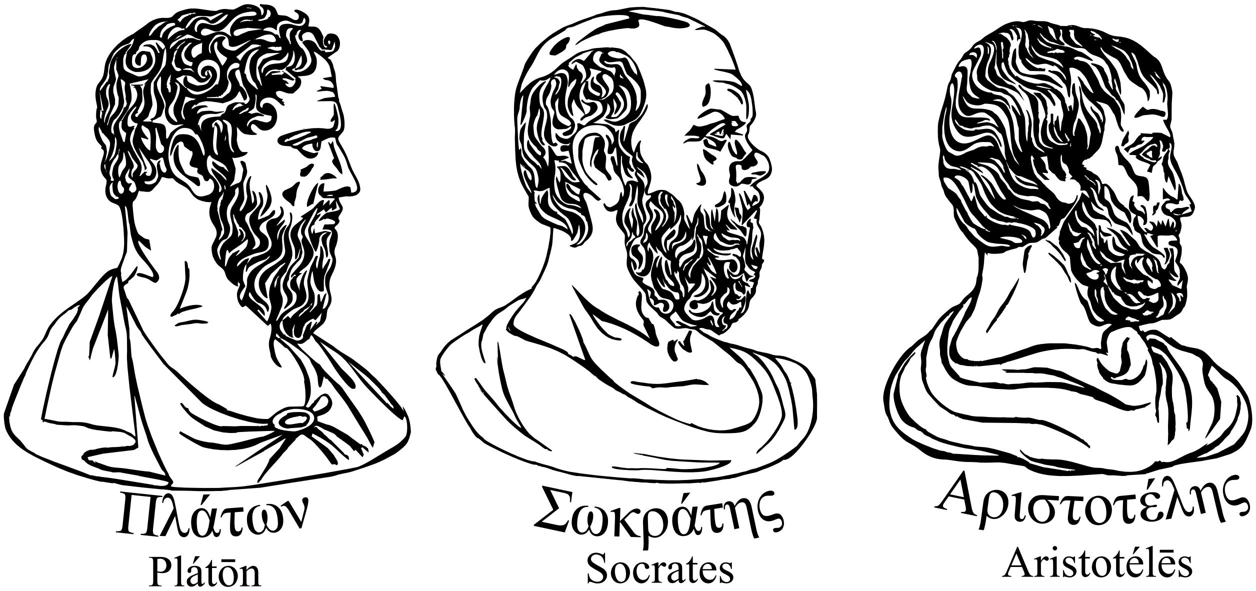
1.2.1 Early scientists

When you think of scientists, what image do you have in your mind? Albert Einstein? Marie Curie? Unfortunately, scientists are sometimes poorly portrayed as stereotypes in the media. The fact is, scientists are normal people who live similar lives to the rest of us.

Before putting on 'the shoes of a scientist' to conduct your own investigation, it's worth asking the question 'What, or who, is a scientist?' The answer to that question has been changing constantly for more than 2000 years.

The ancient Greek 'scientists' were very different from the scientists of today. They were called philosophers. The ancient Greek philosophers were curious and made accurate observations but they didn't perform experiments to test their ideas. They were thinkers, who tried to explain the structure of matter, the sun and the night sky. They walked the streets, discussing their ideas about nature, politics and religion with each other and their followers.

FIGURE 1.3 The Ancient Greek philosophers were some of the first people to question the nature of the world.



Although the ideas of the ancient Greek philosophers were limited by a lack of technology, they provided a stepping stone for the more recent growth in scientific knowledge.

One of the early Greek philosophers was Democritus who, in about 500 BC, suggested that all matter was made of tiny particles.

Aristotle, born in Greece fourteen years after the death of Democritus, reasoned that all matter was composed of four elements — earth, air, fire and water. About 2000 years later, Scottish scientist Joseph Black (1728–1798) discovered a fifth 'element'. He had discovered a new gas that he called 'fixed air'. We now call the gas carbon dioxide and know that it is not an element.

DISCUSSION

Find out about the Hippocratic Oath and discuss why it is important to medical practitioners.

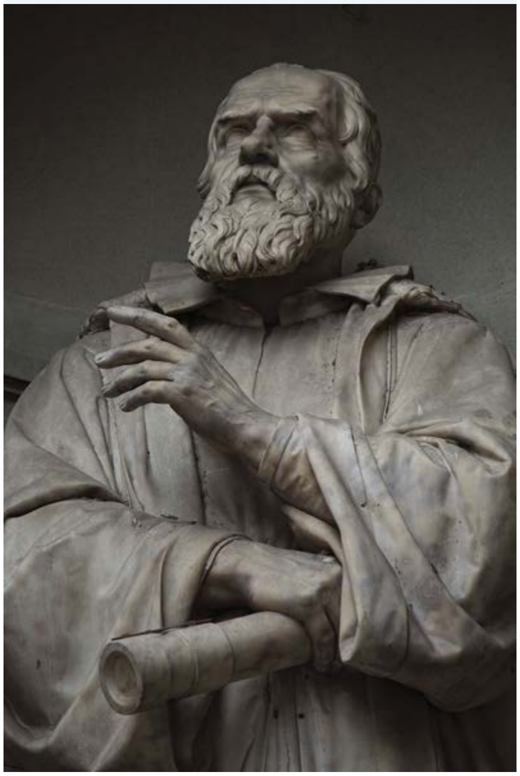
There are many other examples, including Hippocrates, born in the same year as Democritus, who taught his medical students to use observation rather than theory to diagnose illness. Hippocrates is regarded by many as the father of modern medicine.

Almost without exception, present-day scientific discoveries depend on work done previously by other scientists.

1.2.2 The scientific revolution

The way in which scientists worked changed greatly during the lifetime of Galileo Galilei (1564–1642), who is probably best known for being the first person to use a telescope to study the Moon, planets and stars. Galileo also performed many experiments to investigate the motion of objects on the Earth's surface.

FIGURE 1.4 Galileo Galilei



Galileo wrote about the need for controlled experiments and the importance of accurate observations and mathematical analysis. In fact, Galileo is described by many scientists and historians as the founder of the scientific method.

Galileo's legacy

Some of the great scientists of the seventeenth century who followed Galileo and used the scientific methods he wrote about were:

- Johannes Kepler (1571–1630), who developed a number of laws about the motion of planets around the sun
- William Harvey (1578–1657), who used scientific methods to discover how blood circulates through the human body
- Robert Boyle (1627–1691), who applied the scientific method in chemistry to investigate the structure of matter more than 200 years before the current model of the atom was developed
- Robert Hooke (1635–1703), who used the newly invented microscope to observe and investigate the cells that make up living organisms.

These scientists were followed by Sir Isaac Newton (1642–1727), who was born in the same year that Galileo died. Newton was able to use mathematics to describe and explain the role of gravity in the motion of the Earth and other planets around the Sun. He also explained much of the behaviour of light.

The work of the scientific pioneers of this era has influenced the thinking of those that followed and continues to influence scientists in the twenty-first century.

CASE STUDY: Modelling DNA

Scientific developments are almost always built upon the work of others. Two of the most famous scientists in the field of biochemistry were James Watson and Francis Crick.

Watson and Crick established the structure of deoxyribonucleic acid, or DNA, the substance that makes up genes. Like many scientists, they relied on models to help them understand. Their original model is shown in figure 1.5. They won the Nobel Prize in 1962 for their work.

FIGURE 1.5 Original model of DNA made by Watson and Crick

The model of DNA developed by Watson and Crick was based on the results of other scientists including:

- the work of Erwin Chargaff, who determined the basis of parts of DNA in 1951
- the X-ray diffraction photographs (taken using X-rays rather than light) developed in 1949 by Rosalind Franklin and Maurice Wilkins.

Watson and Crick's breakthrough with DNA was possible thanks to the earlier discoveries of other scientists. Scientists today continue to build on the work of Watson and Crick. Their breakthrough has allowed other scientists to understand inherited diseases, and enabled the new field of genetic engineering to emerge.

FIGURE 1.6 Rosalind Franklin provided an important stepping stone in the discovery of DNA.

These include:

- genetic identity testing for forensic analysis
- identifying genetic diseases including Down syndrome and Huntington disease
- identifying genetic susceptibility to disease, including risks of hereditary breast and ovarian cancer
- genetic sequencing of bacteria and viruses to trace their origin and spread.

Other branches of science work in a similar way. There are many examples of scientists furthering the work done by their colleagues, such as the recent achievements of genetic researchers.

1.2.3 Working in teams

Until the twentieth century, most scientists worked alone, with little or no financial support. Communication between individual scientists was difficult. Many of them wrote to each other and read the work of their fellow scientists. However, the telephone was not invented until 1876 and, of course, there was no email, no computers and no overseas travel except by ship.

Since the early twentieth century, most scientists have worked in teams. Their work is almost always supported and funded by organisations, industry or governments. Communication and teamwork between scientists all over the world are easier to achieve because of phones, video conferencing, the internet, email and jet aircraft.

on Resources

assesson Additional automatically marked question sets

1.2 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. MC Ancient Greek philosophers began the development of what is now called 'the scientific method'. It was based on observations and:
   A. hypotheses
   B. thinking
   C. looking
   D. sleeping.
2. According to Aristotle, all matter was composed of four elements. What were those elements?
3. Why was Galileo described by many as the founder of the scientific method?

Apply and analyse

4. List four of the qualities that you would expect a present-day scientist to have.
5. Why was the period of the seventeenth century labelled 'the scientific revolution'?
6. Name some major technologies that were not available to the early Greeks and that have helped modern scientists to test their hypotheses.
7. Which technologies did seventeenth-century scientists have available to them that the early Greek scientists did not have?

Evaluate and create

8. Imagine that Galileo Galilei could return to a university in Italy today and observe the way in which scientists at the university worked. Write a one-page account of the observations that he might enter into his diary at the end of the day.

Fully worked solutions and sample responses are available in your digital formats.

1.3 Accidents and observations

LEARNING INTENTION

At the end of this subtopic you will be able to explain how advances in scientific understanding often rely on developments in technology and technological advances.

1.3.1 A matter of luck?

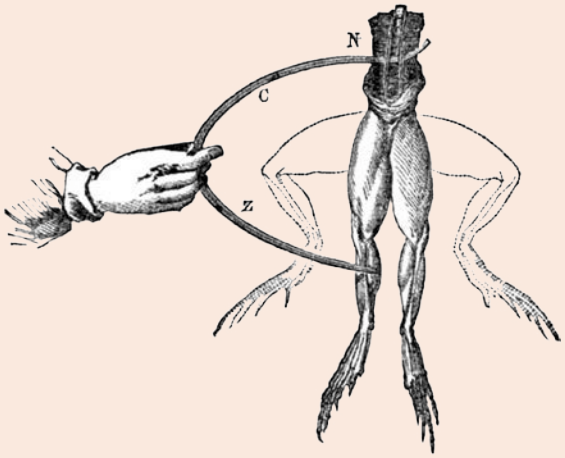
Some of the greatest scientific discoveries have been made by accident. The development of batteries, penicillin and X-rays began with 'accidents' in laboratories. However, was it all just a matter of luck?

CASE STUDY: The world's first electric cell

The very first electric cell was created by accident over 200 years ago. Luigi Galvani, an Italian physician, was dissecting the leg of a recently killed frog. The leg was held by a brass hook (figure 1.7). When he cut the leg with an iron knife, the leg twitched. Galvani investigated further by hanging the frog's legs on an iron railing with brass hooks. Whenever the frog's legs came into contact with the iron railing, they twitched. Galvani incorrectly proposed a theory of 'animal electricity' as the reason behind the muscle spasms.

Reports of Galvani's observations reached his friend Alessandro Volta, another Italian scientist. Volta suggested that the twitch was caused by a sudden movement of electric charge between the two different metals. The frog's flesh, he suggested, conducted the charge. Galvani had, without realising it, produced the world's first electric cell. The **galvanometer**, an instrument used to measure small electric currents, was named after Luigi Galvani.

FIGURE 1.7 Galvani's experiments on frog's legs helped to understand electric charge.



galvanometer an instrument used to measure small electric currents; named after Luigi Galvani

CASE STUDY: X-rays

X-ray images allow doctors, dentists and veterinarians to 'see' through living flesh. The pictures taken with x-rays, called radiographs, are obtained by passing x-rays through objects onto a photographic plate. Unlike light, x-rays pass through the human body. Some parts of the body absorb more of the x-rays than others, leaving a shadow on the plate. Bones leave the sharpest shadows, making it possible to detect fractures and abnormalities.

X-rays have many other uses. They are used in metal detectors at airports and to detect weaknesses and cracks in metal objects. X-rays can be used by archaeologists to examine ancient objects (including Egyptian mummies) found under the ground or in ruins without touching and damaging them.

FIGURE 1.8 X-ray pictures can reveal broken bones and disease in internal organs.

X-rays were discovered by accident in 1895 while German physicist Wilhelm Röntgen (pronounced 'Rentjen') was experimenting with a glass tube that glowed as electrons moved through it at high voltage. He had, by chance, left a photographic plate on a nearby bench. Röntgen noticed that whenever electrons were passing through the tube, the photographic plate glowed. This was puzzling because the glass tube was wrapped in heavy black paper and, since the room was in total darkness, there was no light to expose the photographic plates.

Röntgen investigated his puzzling observations further. He found that these mysterious rays that seemed to be coming from the tube could pass through human flesh as well as black paper. He obtained a clear image of the bones in his wife's hand as she rested it on the photographic film.

Röntgen's accidental discovery changed the face of medical practice in many ways.

CASE STUDY: Penicillin, the drug that changed the world

penicillin a powerful antibiotic substance found in moulds of the genus *Penicillium* that kills many disease-causing bacteria

lysozyme a chemical (enzyme) in human teardrops able to kill some types of bacteria as part of your body's natural defence

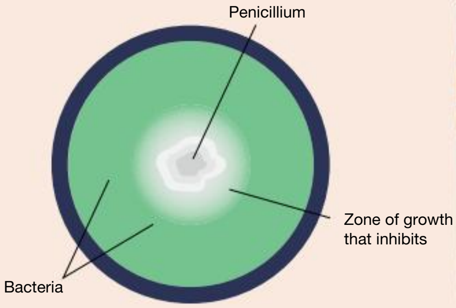
Penicillin is one of the most commonly used drugs in the treatment of diseases caused by bacteria. The discovery and production of penicillin followed a series of accidental observations. The first observation of penicillin was made in 1928 by Scottish bacteriologist Sir Alexander Fleming.

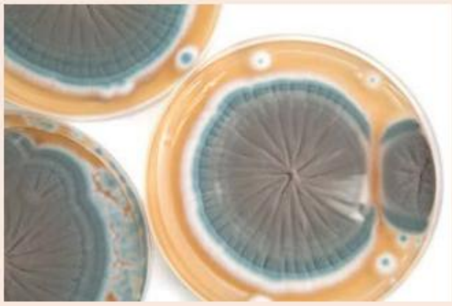
Fleming's interest in bacterial diseases intensified during World War I, when he was treating wounded soldiers. He noticed that the antiseptics used to treat wounds killed white blood cells more quickly than the harmful bacteria they were designed to kill. The white blood cells form part of the body's natural resistance to bacteria.

After the war, Fleming began searching for substances that would kill bacteria without harming the body's natural defences.

One day during his search, a teardrop fell into a dish containing a layer of bacteria. When he checked the dish the following day, he noticed a clear layer where the teardrop had fallen. Fleming then found that a chemical in human teardrops, which he named **lysozyme**, was able to kill some types of bacteria without harming the body's natural defences. Unfortunately, lysozyme was not effective against most disease-causing bacteria.

FIGURE 1.9 Fleming noticed the *Penicillium notatum* mould stopped the growth of bacteria.

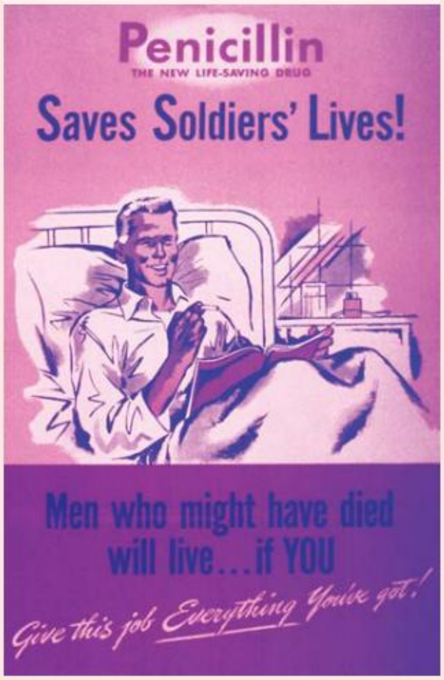




Fleming's greatest discovery occurred in 1928 when he was trying to find a cure for influenza. A tiny piece of mould had fallen into a Petri dish in which he was growing bacteria before the lid was put on. Fleming noticed that there was no further growth of bacteria around the mould (figure 1.9). He later admitted that if it had not been for his earlier experience with the teardrop, he may have thrown the dish away because it had been spoiled.

The mould, *Penicillium notatum*, contained a substance called penicillin, which kills many disease-causing bacteria without harming the body's natural defences. A new problem arose — how to separate and purify the substance. It was an Australian scientist, Howard Florey (1898–1968), who succeeded in separating and purifying the penicillin antibiotic. Together with Boris Chain, a Jewish refugee from Germany, Florey found a way of producing enough penicillin to treat a number of diseases. Their success came just in time for use in treating the many wounded in World War II. Fleming, Florey and Chain shared the Nobel Prize in Medicine in 1945 and their work has saved millions of lives.

FIGURE 1.10 Mass production of penicillin has helped save millions of lives since World War II.



Resources

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1.3 Exercise

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Select your pathway

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

Remember and understand

1. Which modern-day device was accidentally created by Luigi Galvani?
2. What form of radiation was discovered by Wilhelm Röntgen?
3. Which drug was later produced as a result of Alexander Fleming's accidental observation?

Apply and analyse

Your answers to questions 4 and 5 could be presented in a table.

4. Consider the discoveries made by Galvani, Röntgen and Fleming. In each case, describe the skills and scientific knowledge used in making and developing their discovery.
5. Make a list of the personal qualities that enabled Galvani, Röntgen and Fleming to take advantage of their chance observations.
6. Were the discoveries of the electric cell, x-rays and penicillin really just accidents? Explain your answer.

Evaluate and create

7. Do you think that the electric cell, x-rays and penicillin would have been discovered if it had not been for the chance observations of Galvani, Röntgen and Fleming? Explain your answer.

Fully worked solutions and sample responses are available in your digital formats.

1.4 A question of ethics

LEARNING INTENTION

At the end of this subtopic you will be able to explain how ethics guides how science is carried out and the potential conflicts between science and beliefs.

SCIENCE AS A HUMAN ENDEAVOUR: Science and ethics

Ethics is the system of moral principles on the basis of which people, communities and nations make decisions about what is right or wrong. Scientific inquiry takes place in communities that have political, social and religious views and is undertaken by people who have personal views about all sorts of issues. It is a human endeavour and therefore cannot be separated from ethics and questions about right and wrong.

ethics the system of moral principles on the basis of which people, communities and nations make decisions about what is right or wrong

Ethical values vary between countries, religions, communities and individuals — even between members of the same family. For example, capital punishment, the execution of a person for committing a crime, is considered by some to be right and by others to be wrong.

Science interacts with ethics in several ways, including:
- affecting the way in which science is conducted
- affecting the types of scientific research carried out
- in the conflict or match between scientific ideas and religious beliefs
- providing scientific community practices that act as a model for ethical behaviour.

Animal testing

Animals are used in scientific research in many ways, including: to test the effects of potential drugs; to test cosmetics for allergies; to understand the functioning of parts of the body; and to test new surgical techniques. In some research and testing, the animals die. Animals used include monkeys, bees, mice, worms and dogs, among others.

FIGURE 1.11 The European Union has banned the sale of cosmetics tested on animals.

There are ethical issues about whether animals should ever be used in scientific research, or if some types of animals shouldn't be used, or if some types of research shouldn't be carried out at all.

DISCUSSION

Should animals be used for testing in the development of cosmetics? What about in drug development?

Medical research

Medical research is carried out partly by public institutions such as universities and specialist research departments, and partly by private companies. Traditionally, the main purpose of research in public institutions has been to increase understanding and to provide solutions to existing problems; while private companies aim to provide new products or services that can be sold for profit. However, increasingly many research institutions are developing their discoveries into commercial ventures. Whether the research is conducted by private or public research institutions, the ethics of any new drug production should be examined to balance profitability and the benefit to the community.

Life expectancy varies greatly around the world, as do patterns of disease. Cancer, heart disease and diabetes kill many Australians and billions of dollars are spent on researching their causes and treatment. Diarrhoeal diseases and malaria are readily treated in Australia, but kill millions of people each year in Africa, Asia and South America — sometimes because of lack of information and sometimes because of lack of low-cost products. This raises ethical and social questions, such as:
- Is it right that effective drugs are unavailable to millions because of their cost?
- What is the fundamental purpose of developing pharmaceuticals?
- Should the type of treatment be determined by the profit it generates?

The ethics of new drug testing should also be examined. When pharmaceutical companies design new drugs, they need to test these thoroughly before being able to sell them. Some people argue that the testing regime is too lengthy and that new drugs that have the potential to treat deadly diseases should be supplied to the people dying from these diseases even if the drug has not been fully tested. Other people believe that a drug should undergo lengthy testing to ensure no harm is done, even if inadvertently.

DISCUSSION

In the case of a global pandemic, do you think the process of human trials for potential cures or vaccines should be less rigorous? What if it means new drugs could be developed more quickly?

Agriculture

Traditional plant breeding methods — manually putting pollen from one plant into the flower of another to produce a 'cross'— were once the only means of modifying plant types; a slow and laborious process. Now, using techniques for moving genes from one plant to another, it is possible to design plants that have certain characteristics. This technique of **genetic modification (GM)** is controversial. GM crops are greatly restricted in Australia. GM techniques have been used to produce crops that:

- are resistant to herbicide so that weed control is more effective (canola)
- produce their own pesticides to reduce insect attack (cotton)
- contain added nutrients (rice).

Discussion about the ethics of GM crops often focuses on the role of companies in developing GM crops for the profit they are expected to bring. Ethical issues are also raised about whether GM techniques should be used by public research laboratories and international agencies to improve food supply in regions where many people are undernourished.

EXTENSION: Unusual research methods uncover the cause of stomach ulcers

When Barry Marshall and Robin Warren came to the conclusion that stomach ulcers were probably caused by a bacteria, they were faced with some tricky ethical and safety considerations. A stomach ulcer occurs when the lining of the walls of the stomach becomes damaged and the acid inside the stomach eats away at the stomach wall. It is a very painful condition. Previously it was thought that ulcers were caused by lifestyle factors, including stress, so it was difficult to treat ulcers. People were usually told to avoid stress, for example by changing job or cutting their work hours, and to cut out particular foods, sometimes with no improvement to their health.

FIGURE 1.12 *Helicobacter pylori* bacteria in the human stomach cause stomach ulcers. They move their hair-like structures to travel around the stomach lining.

Barry Marshall and Robin Warren suspected that ulcers were actually caused by bacteria called *helicobacter pylori*. They had found these bacteria in the stomachs of people suffering from stomach ulcers but not in the stomachs of healthy individuals. They had also studied the bacterium. The only way to know for sure would be to deliberately infect someone with the bacteria and find out whether they developed a painful ulcer. There were risks involved; for instance, the bacteria could cause other health problems. It could even kill the patient. There were also ethical issues associated with deliberately trying to make a healthy person sick. In the end, Barry Marshall carefully weighed up the risks involved and decided to test his hypothesis on himself. He swallowed a solution of the bacteria and soon became ill and developed the early symptoms associated with the development of stomach ulcers. He then treated himself with antibiotics. Now when a patient is diagnosed with a stomach ulcer, treatment is simple — a course of antibiotics usually fixes the problem.

on Resources

assesson Additional automatically marked question sets

genetic modification (GM) the technique of modifying the genetic structure of organisms making it possible to design organisms that have certain characteristics

1.4 Exercise

learnON

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Select your pathway

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

Remember and understand

1. Identify an illness that affects people worldwide and kills millions in poor countries but almost no-one in Australia.
2. Explain why scientific inquiry should not take place without considering whether it is right or wrong.
3. Explain how GM crops are different from other crops.

Apply and analyse

4. Describe the ethical issues associated with the experiment carried out by Barry Marshall.
5. What does a bioethicist do? What training does a bioethicist require?

Evaluate and create

6. Justify your opinion of the following issue. All medical research, including research into new drugs, should be done by non-profit organisations rather than by companies aiming to make a profit.
7. Justify your opinion of the following issue. Food made from genetically-modified crops should have a special label to show that it contains GM ingredients.
8. Outline some of the arguments for and against using genetically-modified crops. Discuss your arguments with other students in your class or use a PMI (Plus, Minus, Interesting) chart to summarise your arguments.

Fully worked solutions and sample responses are available in your digital formats.

1.5 Your own investigation

LEARNING INTENTION

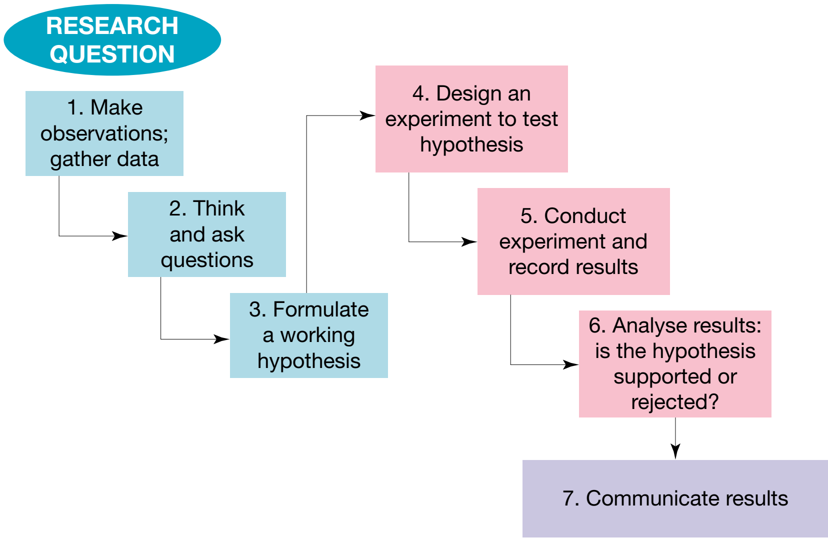
At the end of this subtopic you will understand the scientific method and be able to design your own investigation with attention to variables, reports and scientific processes.

1.5.1 The scientific method

As a science student you are required to undertake scientific investigations. These investigations will not only help you understand scientific concepts, they can be a lot of fun! Scientists around the world all follow what is known as the **scientific method** (figure 1.13). This allows scientists to examine each other's work and build on the scientific knowledge gained. An important aspect of science is being able to reproduce someone else's experiment. The more evidence a scientist has about a theory, the more accepted the theory will be.

scientific method a systematic and logical process of investigation to test hypotheses and answer questions based on data or experimental observations

FIGURE 1.13 The scientific method



The skills you will develop in conducting scientific investigations include the following:

- questioning and predicting
- planning and conducting
- recording and processing
- analysing and evaluating
- communicating scientifically.

Whenever you take a trip away from home, you need to plan ahead and have some idea of where you are going. You need to know how you are going to get there, what you need to pack and have some idea of what you are going to do when you get there.

It's the same with an experimental investigation. Planning ahead increases your chances of success.

Finding a topic

The first step in the scientific method is to develop a research question. You can think of this as finding a topic. Your investigation is much more likely to be of high quality if you choose a topic that you will enjoy working on. These steps might help you choose a good topic:

1. Think about your interests and hobbies. They might give you some ideas about investigation topics.
2. Make a list of your ideas.
3. Brainstorm ideas with a partner or in a small group. You might find that exchanging ideas with others is very helpful.
4. Find out what other students have investigated in the past. Although you will not want to cover exactly the same topics, investigations performed by others might help you to think of other ideas.
5. Do a quick search in the library or at home for books or newspaper articles about topics that interest you. Search the internet. You might also find articles of interest in magazines or journals. You could use a table like table 1.1 to organise your ideas.

TABLE 1.1 Summary of topic research

Topic area	Name of book, magazine, website etc.	Chapter or article	Topic ideas

FIGURE 1.14 Finding a topic to investigate

Making observations and asking questions

Many ideas for scientific investigations start with a simple observation. Some well-known investigations and inventions from the past started that way. Even though the discoveries by Galvani, Röntgen and Fleming described in the case studies of subtopic 1.3 were made by accident, they would not have been made without observation skills. There are also other important 'ingredients' in these discoveries — curiosity and the ability to ask questions and form ideas that can be tested by experiment and further observation.

Danish scientist Hans Oested discovered the connection between electric current and magnetism when, in 1819, he noticed that a compass needle pointed in the wrong direction every time it was placed near a wire carrying an electric current. He went on to design experiments to find out exactly how different electric currents affected compass needles. The results of his experiments started a flood of inventions, including electric generators and motors.

An investigation by a 15-year-old student began with an observation that her friends seemed to perform better in athletic events when there was an audience cheering them on. You have probably seen this yourself. Her investigation 'Does an audience affect the performance of an athlete?' involved three different sporting activities and compared the performance of a large group of students under three different conditions:

- no audience
- a quiet audience
- a cheering audience.

The sporting activities were:

- goal shooting in basketball
- sit-ups
- shot-put.

FIGURE 1.15 Could an audience really affect this team's performance? To answer this question scientifically, an investigation is needed.

What do you think she found out? Perhaps you could try a similar investigation.

Defining the question

Once you have decided on your topic, you need to determine exactly what you want to investigate. It is better to start with a simple, very specific question than a complicated or broad question. For example, the topic 'earthworms' is very broad. There are many simple questions that could be asked about earthworms.

For example:

- Which type of soil do earthworms prefer?
- How much do earthworms eat?
- Do earthworms prefer meat or vegetables?
- How fast does a population of earthworms grow?

FIGURE 1.16 There are many problems relating to earthworms that could be investigated.

Your question needs to be realistic. In defining the question, you need to consider whether:

- you can obtain the background information that you need
- the equipment that you need is available
- the investigation can be completed in the time you have available
- the question is safe to investigate.

1.5.2 Keeping records

A **logbook** is an essential part of a long scientific investigation. It provides you with a complete record of your investigation, from the time you begin to search for a topic. Your logbook will make the task of writing your report very much easier.

logbook a complete record of an investigation from the time a search for a topic is started

bibliography list of references and sources at the end of a scientific report

blog a personal website or web page where an individual can upload documents, diagrams, photos and short videos, add links to other sites and invite other people to post comments

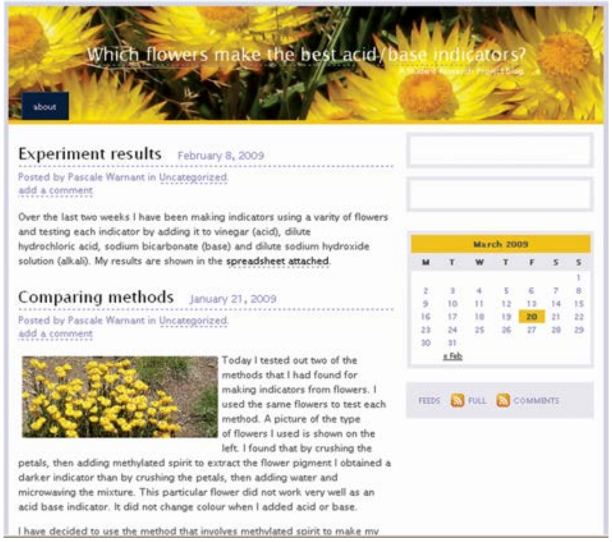
A logbook is just like a diary. Make an entry whenever you spend time on your investigation. Each entry should be clearly dated. It's likely that the first entry will be a mind map or list of possible topics. Other entries might include:

- notes on background research conducted in the library; include all the details you will need for the **bibliography** of your report (see section 1.5.8)
- a record of the people that you asked for advice (including your teacher), and their suggestions
- diagrams of equipment, and other evidence that you have planned your experiments carefully
- all of your 'raw' results, in table form where appropriate
- an outline of any problems encountered and how you solved them
- first drafts of your reports, including your thoughts about your conclusions.

An online logbook

An exercise book can be used as a logbook, but there are several advantages in maintaining your logbook online in the form of a **blog** or in a program such as OneNote. If you choose to use a blog to record your investigation, there are many sites that will allow you to set up a free blog (figure 1.17). Your teacher might be able to provide some suggestions. Once you set up a blog, every entry you make will be dated automatically. You can upload documents, diagrams, photos and short videos. You can also add links to other sites and invite friends, family and teachers to post comments about your progress.

FIGURE 1.17 A blog used as a logbook for a student research investigation



There are some precautions that you should take if you decide to use a blog as a logbook.

- Limit your posts to those related to your science investigation. Don't use your logbook blog for social networking.
- Do not include your address or phone number.
- If your blog is on the internet (rather than a school intranet):
  - do not post any photos of yourself in school uniform or any other clothing that will identify where you go to school
  - do not include your full name, address, phone number or the name of your school in the blog. Use only your first name or a nickname.
  - use privacy settings or use a password to ensure that only trusted school friends, family and your teacher have access to the blog.

1.5.3 Designing the experiments

In order to complete a successful investigation, you need to make sure that your experiments are well designed. Once you've decided exactly what you are going to investigate, you need to be aware of:

- which variables need to be controlled and which variables can be changed
- whether a control is necessary
- what observations and measurements you will make and what equipment you will need to make them
- the importance of repeating experiments (replication) to make your results more reliable
- how you will record and analyse your data.

A poorly designed investigation is likely to produce a conclusion that is not **valid**.

Understanding variables

A **variable** is an observation or measurement that can change during an experiment. You should change only one variable at a time in an experiment.

It is important you understand and identify the different types of variables in your experiment.

- **Independent variable**: the variable that you deliberately change during an experiment.
- **Dependent variable**: the variable that is being affected by the independent variable — that is, the variable you are measuring.

For example, if you were performing an experiment to find out which brand of fertiliser was best for growing a particular plant, the independent variable would be the brand of fertiliser. The dependent variable would be the heights of the plants after a chosen number of days.

When you are testing the effect of an independent variable on a dependent variable, all other variables should be kept constant. Such variables are called **controlled variables**. For example, in the fertiliser experiment, the type of plant, amount of water provided to each plant, soil type, amount of light, temperature and pot size are all controlled variables. The process of controlling variables is also known as **fair testing**.

valid sound or true. A valid conclusion can be supported by other scientific investigations.

variable quantity or condition that can be changed, kept the same or measured during an experiment

independent variable a variable that is deliberately changed during an experiment

dependent variable a variable that is expected to change when the independent variable is changed. The dependent variable is observed or measured during the experiment.

controlled variables the conditions that must be kept the same throughout an experiment

fair testing a method for determining an answer to a problem without favouring any particular outcome; another name for a controlled experiment

Writing a hypothesis

A hypothesis is a statement that predicts what you think will happen in your experiment. It links the independent and dependent variables in a sentence, which can be both tested and proven wrong.

A hypothesis a tentative, testable and falsifiable statement for an observed phenomenon that acts as a prediction for the investigation.

The need for a control

Some experiments require a **control**. A control is needed in the fertiliser experiment to ensure that the result is due to the fertilisers and not something else. The control in this experiment would be a pot of plants to which no fertiliser was added. All other variables would be the same as for the other three pots.

FIGURE 1.18 A control is used to compare the difference in growth to a plant with no fertiliser.

Valid experiments

A valid experiment measures what it actually sets out to measure. If your aim was to find out whether watering plants with sea water affects their growth rate, comparing the number of radish seeds that germinate after one week when watered with tap water or sea water would not be a valid method because it does not actually measure growth rate. It tests the effect of sea water on seed germination.

control an experimental set-up in which the independent variable is not applied that is used to ensure that the result is due to the variable and nothing else

reliable data data that is able to be replicated in different circumstances but the same conditions

Repeatable and reliable experiments

Replication is the repeating of an experiment to make sure you have collected **reliable data**. In the case of the fertiliser experiment, a more reliable result could be obtained by setting up two, three or four pots for each brand of fertiliser or having a number of seedlings in each pot. The results are checked for consistency and an average result for each brand or the control could then be calculated. An average result for each brand or the control could then be calculated.

A reliable experiment provides consistent results when repeated, even if it is repeated on different days and under slightly different conditions; for example, in a different room or with a different researcher collecting the data. Replication increases the reliability of an experiment. This can involve simply doing the same experiment a few times, or having different groups repeat the same experiment and pooling the data gathered by each group when writing the report.

Surveys

A survey is a list of questions that you ask to a large group of people. Some surveys are read out, sometimes over the phone. Some require participants to fill in a form, and increasingly surveys are done online. Surveys are used to collect census data, for market research, to find out what product characteristics consumers find most appealing, to determine voting intentions and also for scientific purposes. A great deal of data about health and lifestyle has been gathered through the use of surveys, sometimes in combination with other tests. To investigate whether there is a link between diet and blood pressure, researchers might collect data about the participant's diet through the use of a survey.

FIGURE 1.19 Surveys are often conducted using multiple-choice questions.

These are some features of well-designed surveys:
- A large sample size is used — many participants take part in the survey.
- Questions are unambiguous — participants can understand the questions.
- A control group is used or, where appropriate, different degrees of exposure to the factor under investigation. An investigation on the effect of loud music on hearing could include a survey where participants were asked about the number of concerts and dance parties they attended over the last 12 months and the participants' hearing could be tested. The data would be of little value if all the participants had a similar level of exposure to loud music. The participants need to be people who are exposed to loud music frequently, some occasionally and some rarely.
- Data can be analysed mathematically. Multiple-choice questions often lend themselves better to this type of analysis.

1.5.4 Using information and communications technology

Computer hardware and software are important tools used by scientists during their investigations.

For example:
- spreadsheets can be used to organise and analyse data
- data loggers can be used to collect large numbers of measurements of variables that are difficult to collect in other ways
- databases can be used to arrange data or information so that it is easier to locate.

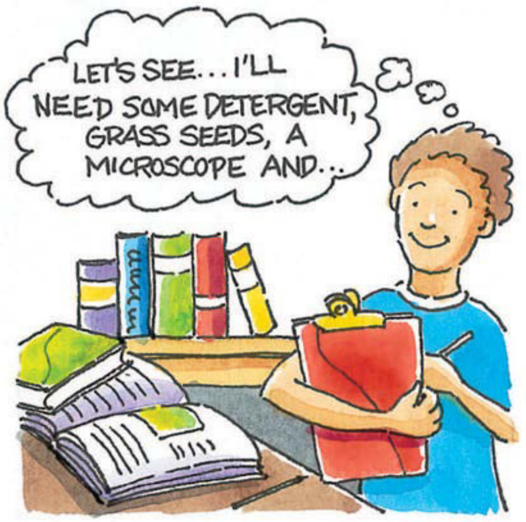
These tools are described in subtopics 1.12 and 1.13.

1.5.5 Getting approval

You should now be ready to write a plan for your investigation. You should not commence any experiments until your plan has been approved by your science teacher. Your plan should include the information below.

1. **Title**
   The likely title — you may decide to change it before your work is completed. The title should be in the form of a question; for example, how does watering grass seeds with a detergent solution affect their growth?
2. **The problem**
   A statement of the question that you intend to answer. Include a hypothesis. A hypothesis is an educated guess about the outcome of your experiments. It is usually based on observations and able to be tested by further observations or measurements.
3. **Outline of your experiments**
   Outline how you intend to go about answering the question. This should briefly outline the experiments that you intend to conduct.
4. **Equipment**
   List here any equipment that you think will be needed for your experiments.
5. **Resources**
   List here the sources of information that you have already used and those that you intend to use. This list should include library resources, organisations and people.

FIGURE 1.20 Write out a plan for your investigation.



1.5.6 Gathering data

Once your plan has been approved by your teacher, you may begin your experiments.

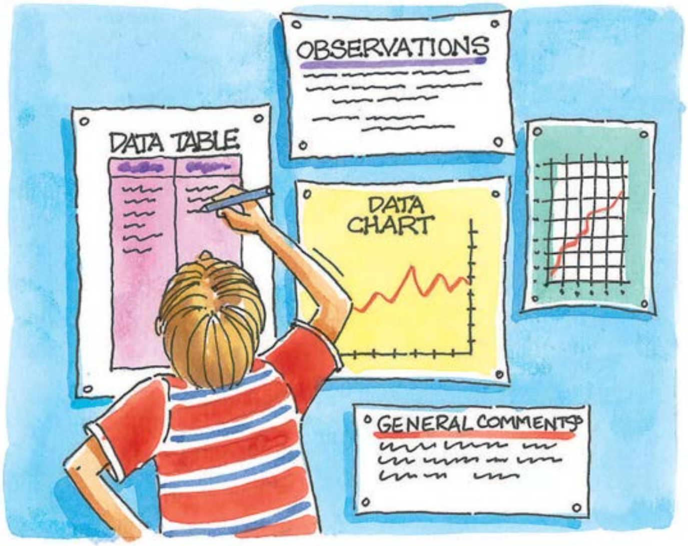
Details of how you conducted your experiments should be recorded in your logbook. All observations and measurements should be recorded. Use tables where possible to record your data.

Where appropriate, measurements should be repeated and an average value determined. All measurements — not just the averages — should be recorded in your logbook.

Photographs or videos should be taken if appropriate.

You might need to change your experiments if you get results you don't expect. Any major changes should be checked with your teacher.

FIGURE 1.21 All observations and measurements should be recorded.



Precision and accuracy

As you plan and carry out your investigation you need to ensure that the data you collect is **precise** and **accurate**. Choosing the most appropriate instruments to make your measurements is important.

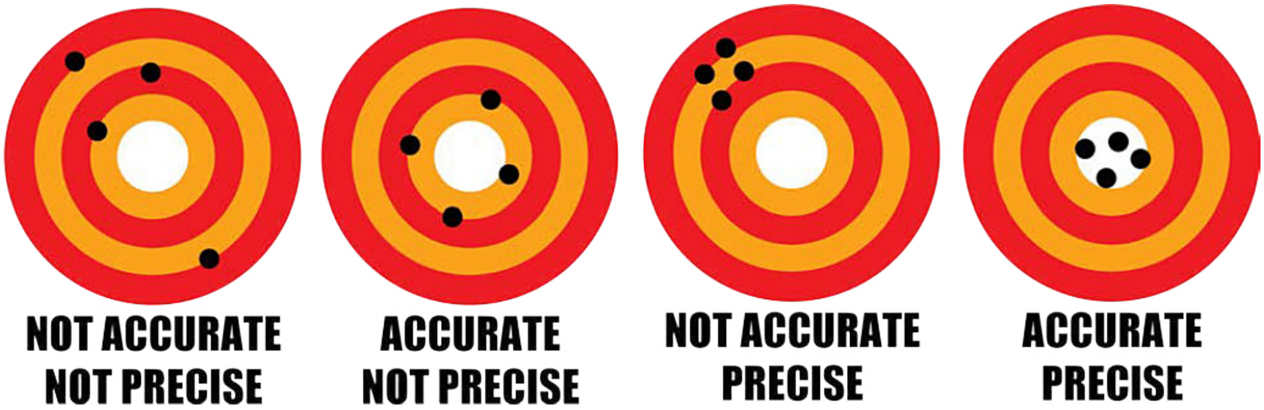
- Precision refers to how close multiple measurements of the same investigation are to each other.
- Accuracy refers to how close an experimental measurement is to a known value.

precise refers to how close multiple measurements of the same investigation are to each other

accurate refers to how close an experimental measurement is to a known value

If an archer is precise, their arrows hit close to one another. If an archer is accurate, their arrows hit close to the target. This is illustrated in figure 1.22.

FIGURE 1.22 Comparing precision and accuracy



Choosing equipment for precision

Choosing the correct piece of equipment is critical to ensure that your results are precise. Your bathroom scales and the electronic scales in a science laboratory both measure mass, but the laboratory scales are more precise. Your school might have different sets of scales that measure to one or two decimal places. Scales that measure to two decimal places are more precise. High-precision scales are needed for some of the senior chemistry experiments.

For measuring instruments with a scale, such as thermometers, rulers and measuring cylinders, the graduations (lines) on the scale give an indication of the precision of the instrument. Generally, an instrument with smaller gradations is more precise,

FIGURE 1.23 Precision laboratory scales

Measuring volumes of liquids

When liquids are placed in a vessel, the surface of the liquid is often curved. This curved surface of a column of liquid is called a meniscus. When measuring the volume of a liquid, make sure you read the volume from the bottom of the meniscus, not the top.

SAMPLE PROBLEM 1: Measuring readings of a meniscus

What is the measurement of this liquid in a measuring cylinder?

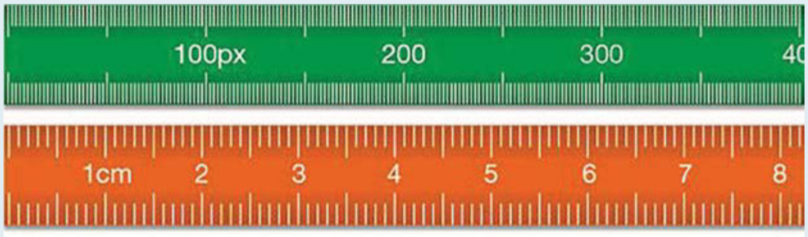
THINK	WRITE
1. The liquid level should be read from the bottom of the meniscus, not where it touches the glass. Imagine a line drawn across from the bottom of the meniscus to the glass.	
2. Look for the scale marking below the liquid level and above the liquid level. These are 55 mL and 60 mL.To calculate the volume between the two scale markings, subtract the smaller reading from the larger reading.	60 – 55 = 5
3. There are five divisions between these two scale markings. To determine the size of each small scale marking, divide the volume calculated in step **2** by 5.	5 ÷ 5 = 1 Each scale division is 1 mL.
4. To read the measurement of the liquid level, count up from the lower scale marking, 55, to the liquid level; this is two scale divisions.	55 + 2 = 57 mL

SAMPLE PROBLEM 2: Precision

Which of the rulers in the diagram below is the more precise?

Ruler A

Ruler B



THINK	WRITE
Look at the number of divisions on each ruler between each marked measurement. On ruler A, between 100 and 200, there are 50 divisions. On ruler B, between 2 cm and 4 cm, there are 20 divisions.	As ruler A has more graduations over the same space as ruler B, ruler A is more precise.

Ensuring equipment is accurate

Measurements can be very precise, but incorrect. Every so often current affair programs bring attention to service stations that overcharge consumers for petrol by having faulty petrol pumps that give inaccurate readings of the amount of petrol delivered by the pump. For each litre of petrol pumped, the machine might give a reading of 1.1 L and the customer is charged accordingly. The machine is quite precise, but not accurate.

CASE STUDY: Calibrating a pH meter

Some measuring instruments require **calibration** to ensure that they provide accurate measurements. The calibration might be part of the manufacturing process, or it may need to be carried out by the user regularly. A pH meter is a device that needs to be calibrated regularly (figure 1.24). pH is a measure of the acidity of a substance. You can measure pH with a universal indicator. For a more precise reading a pH meter can be used. It is a device that is placed in the solution and it gives a reading of the pH to one or two decimal places. Over time it can lose its calibration and give inaccurate readings. A reading of 6.25 might be displayed when the solution actually has a pH of 5.38. To calibrate the pH meter, you place it in solutions of known pH and adjust the device until it reads the correct values for these solutions. You can then use the meter to measure the pH of a solution with an unknown concentration.

FIGURE 1.24 A pH meter needs to be calibrated regularly to ensure it gives accurate readings.

1.5.7 Graphing variables

Many different types of data can be collected in scientific experiments. Data is often presented in tables or as graphs.

Tables

Tables can be used to record data to help separate and organise your information. All tables should:

- have a heading
- display the data clearly
  - the independent variable in the first column
  - the dependent variable(s) in later columns
- include units in the column headings and not with every data point
- be designed to be easy to read.

calibration the process whereby a measuring instrument is restored to accuracy

Always include a title for your table.

Include the measurement units in the headings.

The column heading show clearly what has been measured.

TABLE 1.2 The effect of different brands of fertiliser on the growth of seedlings

Fertiliser	Day 2 Height (cm)	Day 4 Height (cm)	Day 6 Height (cm)	Day 8 Height (cm)	Day 10 Height (cm)
Brand X	2	3	5	6	9
Brand Y	3	5	7	9	11
Brand Z	1	2	3	5	7
Control	0	0.6	1.8	2.5	4

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

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

Graphs

Graphs can help you see patterns and trends in your data. Once your data has been recorded in a table, you need to work out what is the best graph to choose. You can do this by recognising what type of data you have.

qualitative data (or categorical data) data expressed in words

quantitative data (or numerical data) data that can be precisely measured and have values that are expressed in numbers

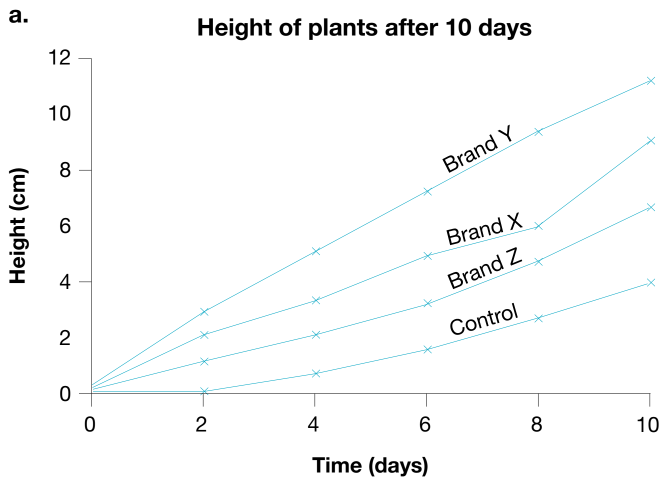
- **Qualitative data** is expressed in words. It is also known as categorical data – you can think of this data as falling into categories. It is descriptive and not numerical and can be easily observed but not measured. In our experiment with the fertiliser, the brands of fertiliser is qualitative data. There are two types of qualitative data:
  - *ordinal data* can be ordered or ranked; this could be levels (1st, 2nd, 3rd…) or opinions (strongly agree, agree, disagree, strongly disagree)
  - *nominal data* cannot be organised in a logical sequence; this could include colours or brand names.
- **Quantitative data** (or numerical data) can be precisely measured and have values that are expressed in numbers. In our experiment with the fertiliser, the height of the seedlings is quantitative data. There are two types of quantitative data:
  - *continuous data* can take any numerical value, such as the change in temperature of a cup of coffee over time
  - *discrete data* can only take on set values that can be counted, such as the number of protons in an atom or the change in temperature of a cup of coffee in different types of cups after 10 minutes.

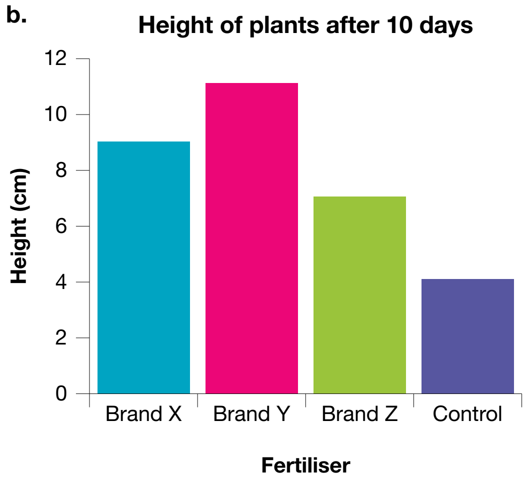
The most common types of graphs are listed below.

- *Scatterplots*: require both sets of data to be numerical (or quantitative). Each dot represents one observation. A scatterplot can easily show trends between data sets, and correlations can be seen.
- *Line graphs*: a scatterplot with the dots joined. The dots are usually joined using a straight line, but sometimes the line is curved. They are used for continuous data.
- *Bar/Column graphs*: when one piece of data is qualitative and the other is quantitative. The bars are separated from each other. The horizontal axis has no scale because it simply shows categories. The vertical axis has a scale showing the units of measurements.
- *Histograms*: a special kind of bar graph that show continuous categories, and are often used when examining frequency. The bars are not separated.
- *Pie charts and divided bar charts*: used to show frequencies or portions of a whole. This includes percentages or fractions.

You would normally graph the independent variable (the one you changed) on the *x*-axis, and the dependent variable (the one you measured) on the *y*-axis. When the dependent variable changes with time, you can graph time on the *x*-axis and the dependent variable on the *y*-axis. For example, in the fertiliser experiment, two types of graphs could be used, a line graph or a column graph (bar chart).

FIGURE 1.25 a. Line graph of the growth of plants over 10 days in different brands of fertiliser. **b.** Column graph of the height of plants at the end of 10 days in different brands of fertiliser.





SAMPLE PROBLEM 3: Choosing types of graphs

Identify the type of graph that would be most appropriate to display the following data:

a. Data from Melbourne Zoo showing how the mass of a baby elephant has increased over time

b. The mass of each elephant at Melbourne Zoo

c. The proportion of visitors using various modes of transport to travel to Melbourne Zoo.

Think	Write
a. The mass of one elephant is a number that changes over time, so it is quantitative data. Mass can take any numerical value, so it is continuous data.	Mass is continuous data, so a line graph would be the best choice.
b. We compare the mass of different elephants by showing the name of each elephant and its mass at a set point in time. The name of each elephant is qualitative, and the mass of each elephant is quantitative (continuous).	As we have both qualitative and quantitative data, a bar or column graph would be the best choice.
c. The proportion of visitors using various modes of transport shows fractions or percentages of a whole.	As the data is showing the proportion of people using different modes of transport, the best choice would be a pie chart or divided bar chart.

1.5.8 Writing your report

You can begin writing your report as soon as you have planned your investigation, but it cannot be completed until your observations are complete. Your report should be typed or neatly written on A4 paper and presented in a folder. It should begin with a table of contents, and the pages should be numbered. Your report should include the following headings (unless they are inappropriate for your investigation).

Scientific report structure

Abstract

The abstract provides the reader with a brief summary of your whole investigation. Even though this appears at the beginning of your report, it is best not to write it until after you have completed the rest of your report.

Introduction

Present all relevant background information. Include a statement of the problem that you are investigating, saying why it is relevant or important. You could also explain why you became interested in the topic.

Aim

State the purpose of your investigation: that is, what you are trying to find out. Include the hypothesis.

Materials and methods

Describe in detail how you did your experiments. Begin with a list or description of equipment that you used. You could also include photographs of your equipment if appropriate. The method description must be detailed enough to allow somebody else to repeat your experiments. It should also convince the reader that your investigation is well controlled. Labelled diagrams can be used to make your description clear. Using a step-by-step outline makes your method easier to follow.

Results

Observations and measurements (often referred to as data) are presented here. Data should, wherever possible, be presented in table form so that they are easy to read. Graphs can be used to help you and the reader interpret data. Each table and graph should have a title. Make sure you use the most appropriate type of graph for your data. Some examples of graphs are shown in section 1.5.7.

Discussion

Discuss your results here. Begin with a statement of what your results indicate about the answer to your question. Explain how your results might be useful. Any weaknesses in your design or difficulties in measuring could be outlined here. Explain how you could have improved your experiments. What further experiments are suggested by your results?

Conclusion

This is a brief statement of what you found out. It is a good idea to read your aim again before you write your conclusion. Your conclusion should also state whether your hypothesis was supported. You should not be disappointed if it is not supported. In fact, some scientists deliberately set out to reject hypotheses!

Bibliography

Make a list of books, other printed or audio-visual material and websites to which you have referred. The list should include enough detail to allow the source of information to be easily found by the reader. Arrange the sources in alphabetical order.

The way a resource is listed depends on whether it is a book, magazine (or journal) or website. For each resource, list the following information in the order shown:

- author(s), if known (book, magazine or website)
- title of book or article, or name of website
- volume number or issue (magazine)
- URL (website) and the date you accessed the web page
- publisher (book or magazine), if not in title
- place of publication, if given (book)
- year of publication (book, magazine or website)
- chapter or pages used (book).

Some examples of different sources are listed below:

- Taylor, N., Stubbs A., Stokes, R. (2020) *Jacaranda Chemistry 2 VCE Units 3 & 4*. 2nd edition. Milton: John Wiley & Sons.
- Gregg, J, (2014) 'How Smart are Dolphins?' *Focus Science and Technology*, Issue 264, February 2014, BBC, pages 52–57
- Australian Marine Wildlife Research & Rescue Organisation, accessed 26 June 2020, <http: www.amwrro.org.au,2014>.

Acknowledgements

List the people and organisations who gave you help or advice. You should state how each person or organisation assisted you.

1.5.9 Everyone has talent

In most states and territories, there are competitions or events that provide opportunities for you to present reports of your own scientific research. Each year, tens of thousands of dollars in prizes are awarded to hundreds of entrants. Information about these competitions and events can be obtained from your science teacher.

on Resources

eWorkbooks Setting up a logbook (ewbk-5281)
Variables and controls (ewbk-5283)
Investigating (ewbk-5285)
Organising and evaluating results (ewbk-5287)
Drawing conclusions (ewbk-5289)
Summarising (ewbk-5291)
Evaluating media reports (ewbk-5293)

assesson Additional automatically marked question sets

1.5 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. What is the advantage of repeating an experiment several times?
2. Describe the difference between an independent and a dependent variable.
3. MC In which section of your report do you describe possible improvements to your experiments?
   A. Methods
   B. Results
   C. Discussion
   D. Conclusion
4. Distinguish between precision and accuracy.

5. Outline what calibrating an instrument involves.
6. Describe the use of a control in an experiment with reference to independent and dependent variables.

Apply and analyse

7. Why is it better to write the abstract of a scientific report last, even though it appears at the beginning?
8. Josie wanted to find out whether the water in her drink bottle would stay cold for longer if she wrapped the bottle in foil or a towel. Identify the independent and dependent variable and one variable that would need to be controlled.
9. Charlotte would like to find out whether ice blocks made from green-coloured water melt at the same temperature as uncoloured ice blocks. Identify the independent and dependent variable and one variable that would need to be controlled.
10. Jayden is testing the hypothesis that tall people are faster long-distance runners than short people. Identify the independent and dependent variable and one variable that would need to be controlled.

11. Shinji is testing the idea that plants grow faster if you play them music for at least 2 hours a day. Identify the independent and dependent variable and one variable that would need to be controlled.

Evaluate and create

12. Construct a flow chart to show the steps that you need to take before beginning your experiments.
13. The television show *MythBusters* involves a team led by Adam and Jamie carrying out investigations to test various myths.
    a. Define the term myth. (Use a dictionary if necessary.)
    b. Look at the list of myths Adam and Jamie have investigated and pick at least three that you could test using equipment available at home or at school.
    c. If your school has any episodes of *MythBusters* available, watch an episode. Make a list of the myths tested in the episode and discuss the validity of the experiments carried out by Adam, Jamie and their team.

Fully worked solutions and sample responses are available in your digital formats.

1.6 SkillBuilder — Writing an aim and forming a hypothesis

online only

Why do we need to write aims and hypotheses?

When you conduct a scientific investigation, it is important to write an aim and a hypothesis. An aim is a statement of what you are trying to find out in your investigation. It is simply the reason why you are conducting the investigation. An aim that is simple and clear will allow you to focus on the investigation.

A hypothesis is an idea that is based on observation that may explain a phenomenon and it must be able to be tested. It should be related to your aim and it is a statement, not a question. A hypothesis cannot be proven correct, but the results of your experiment will either support your hypothesis or not support your hypothesis.

Select your learnON format to access:
- an overview of the skill and its application in science (Tell me)
- a video and a step-by-step process to explain the skill (Show me)
- an activity and interactivity for you to practise the skill (Let me do it)
- questions to consolidate your understanding of the skill.

Resources

eWorkbook SkillBuilder — Writing an aim and forming a hypothesis (ewbk-5295)
Video eLesson Writing an aim and forming a hypothesis (eles-4205)
Interactivity Writing an aim and forming a hypothesis (int-8118)

1.7 SkillBuilder — Controlled, dependent and independent variables

online only

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

In order to answer a question scientifically, a controlled investigation needs to be performed. In a controlled investigation, every variable except the one being tested is held constant, which stops the results being affected by an uncontrolled factor. The variable that you are investigating is called the independent variable. The variable that you are measuring is called the dependent variable.

Select your learnON format to access:
- an overview of the skill and its application in science (Tell me)
- a video and a step-by-step process to explain the skill (Show me)
- an activity and interactivity for you to practise the skill (Let me do it)
- questions to consolidate your understanding of the skill.

Resources

eWorkbook SkillBuilder — Controlled, dependent and independent variables (ewbk-5297)
Video eLesson Controlled, dependent and independent variables (eles-4206)
Interactivity Controlled, dependent and independent variables (int-8119)

1.8 SkillBuilder — Measuring and reading scales

online only

How do you read a scale?

In science, a scale or set of numbered markings generally accompanies each measuring device. For example, your ruler measures length, and its scale has markings enabling you to measure with an accuracy of 0.1 cm. When reading a scale, it is important to determine what each of the markings on the scale represents.

A small measuring cylinder can provide a reasonably precise measurement of a volume of water, but if it is not read at eye level the measurement may not be accurate. Measurements should always be made with your eye in line with the reading you are taking. When scales are read from a different angle, the reading is not accurate. This type of reading error is called parallax error.

Select your learnON format to access:
- an overview of the skill and its application in science (Tell me)
- a video and a step-by-step process to explain the skill (Show me)
- an activity and interactivity for you to practise the skill (Let me do it)
- questions to consolidate your understanding of the skill.

on Resources

- eWorkbook — Skillbuilder — Measuring and reading scales (ewbk-5299)
- Video eLesson — Measuring and reading scales (eles-4207)
- Interactivity — Reading scales (int-0201)

1.9 SkillBuilder — Drawing a line graph

online only

What is a line graph?

A line graph displays information as a series of points on a graph that are joined to form a line. Line graphs are very useful to show change over time. They can show a single set of data, or they can show multiple sets, which enables us to compare similarities and differences between two sets of data at a glance.

Select your learnON format to access:

- an overview of the skill and its application in science (Tell me)
- a video and a step-by-step process to explain the skill (Show me)
- an activity and interactivity for you to practise the skill (Let me do it)
- questions to consolidate your understanding of the skill.

on Resources

- eWorkbook — SkillBuilder — Drawing a line graph (ewbk-5301)
- Video eLesson — Drawing a line graph (eles-4208)
- Interactivity — Drawing a line graph (int-8120)

1.10 SkillBuilder — Creating a simple column or bar graph

online only

What is a column or bar graph?

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

Select your learnON format to access:

- an overview of the skill and its application in science (Tell me)
- a video and a step-by-step process to explain the skill (Show me)
- an activity and interactivity for you to practise the skill (Let me do it)
- questions to consolidate your understanding of the skill.

on Resources

- eWorkbook — SkillBuilder — Creating a simple column or bar graph (ewbk-5303)
- Video eLesson — Creating a simple column or bar graph (eles-4209)
- Interactivity — Creating a simple column or bar graph (int-8121)

1.11 Case study

LEARNING INTENTION

At the end of this subtopic you will be able to describe how an investigation is planned and presented as a scientific report.

1.11.1 Investigating muddy water

Sean, a Year 9 student, conducted an experimental investigation to compare the turbidity (cloudiness) of water in the following three locations:

- a creek near his school
- a creek near his home
- a river near his home.

His search for information in the library revealed that the cloudiness was caused by particles of soil (and sometimes pollution) suspended in the water. Sean chose his topic because he was interested in the environment. He felt that clean water was the right of all living things. His research and background knowledge led him to form the hypothesis that 'the clearest water will be in the river'.

Sean took water samples from each of the three locations on 4 days. He found a method of measuring turbidity from a library book. It involved adding a chemical called potash alum to a sample of water in a jar. The potash alum makes the particles of suspended soil clump together and fall to the bottom of the jar. A layer of mud is formed. The height of the mud at the bottom is then measured.

SEAN'S INVESTIGATION

Aim

To compare the turbidity of three local creeks and rivers

Materials

- 4 large jars or bottles with lids for collecting water samples (capacity of about 1 L each)
- 4 identical jam jars with lids, labelled 1, 2, 3 and 4
- metal teaspoon (not plastic, in case it breaks)
- potash alum (potassium aluminium sulfate)
- 4 water samples from different locations
- ruler with 1-millimetre graduations
- 100 mL measuring cylinder
- permanent marker

Method

1. Water samples (about 1 litre each) were collected from a specific part of the creeks and river on the same day.
2. Each of three clean jars was filled to the same level with the water samples — a labelled jar for each location. A fourth labelled jar was filled to the same level with distilled water.
3. One level teaspoon of potash alum was added to each jar. Lids were put on the jars and the jars were shaken.
4. The jars were left for 30 minutes to allow the particles to settle.
5. The height of the layer of mud on the bottom of each jar was measured and recorded.
6. The jars were emptied and washed and the experiment was repeated three more times.
7. Water samples were collected from the same locations on three other days over a ten-day period and the entire experiment was repeated three more times.

A summary of Sean's method, including a list of materials and equipment required, is provided. You will notice that Sean used a fourth sample. It was needed as a control and contained distilled water. This was to ensure that there was nothing in the pure water to cause a layer at the bottom of the jar when the potash alum was added. His results are in table 1.3

TABLE 1.3 Results table measuring the levels of mud in water samples from three areas

	Height of mud (mm)															
	Day 1				Day 2				Day 3				Day 4			
	Test				Test				Test				Test			
Water sample	1	2	3	Average	1	2	3	Average	1	2	3	Average	1	2	3	Average
1. Home creek	3.5	4.0	5.0	4.2	5.0	4.5	5.0	4.8	4.5	5.0	4.5	4.3	5.0	4.5	4.0	4.5
2. School creek	2.5	2.0	2.0	2.2	3.0	2.5	2.5	2.7	2.0	2.5	2.5	2.3	2.0	2.0	2.5	2.2
3. Barnes River	1.0	0.5	0	0.5	2.0	1.0	1.5	1.5	0.5	1.0	0.5	0.7	0.5	0.5	0.5	0.5
4. Distilled water	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

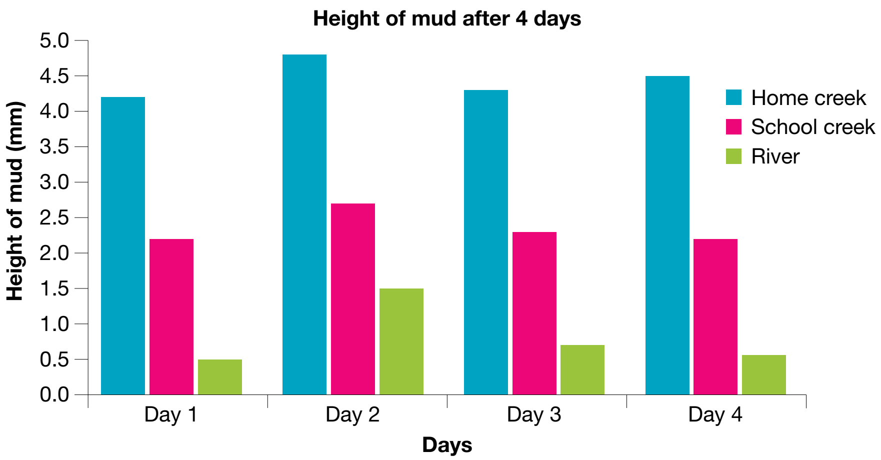
1.11.2 Analysing the data

Sometimes it is necessary to refine the raw data (the data initially collected), presenting them in a different way. Sean was planning to use his average measurements to make a column graph. He decided to simplify his table so that it was easier to construct the column graph. The simplified table (table 1.4) and column graph (figure 1.26) make it easier for others to read the results, and easier for Sean to see patterns and draw conclusions.

TABLE 1.4 Average heights of mud in water from three different areas

	Height of mud (mm)			
Sample number and source	Day 1	Day 2	Day 3	Day 4
1. Home creek	4.2	4.8	4.3	4.5
2. School creek	2.2	2.7	2.3	2.2
3. River	0.5	1.5	0.7	0.5

FIGURE 1.26 Sean's graph makes it easier to see patterns and draw conclusions.



1.11.3 Being critical

Sean was pleased with his results and was able to draw conclusions. In the discussion section of his report, he suggested that further studies be done. The turbidity was affected by weather conditions and the sampling needed to be done over a longer period, and in different weather conditions. Sean had recorded weather details on each day that he sampled water and was able to explain the very high mud level in the river on day 2. It is almost always possible to suggest improvements to your experiments.

1.11.4 Drawing conclusions

Sean's hypothesis, that the clearest water would be in the river, was supported. His conclusion was written in point form.

1. The home creek has the muddiest water, with sample values ranging from heights of 4.2 to 4.8 mm of mud per 200 mL of water. The school creek has moderate amounts of mud compared to the other two samples. Sample values ranged from 2.2 to 2.7 mm of mud per 200 mL of water. The river water is the clearest, with sample values of 0.5 to 1.5 mm of mud per 200 mL of water.
2. Weather conditions can alter the amount of mud in water bodies by either adding run-off from drains or stirring up the water. This was particularly noticeable in the samples taken from the river site on day 2, which followed a period of rain.

Sean's teacher was pleased, and suggested that Sean carry out further research and rewrite his material. They also suggested that he should think about entering his project into a competition.

The last word comes from Sean. After successfully completing his student research project, he said: 'It all depends on the experimental design — get that right and the rest is likely to run smoothly.'

FIGURE 1.27 Chemical waste running into a river. How might you test for such materials in a water sample from this site?

on Resources

assesson Additional automatically marked question sets

1.11 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. For Sean's experiment, identify:
   a. the independent variable
   b. the dependent variable
   c. the variables he controlled.

Apply and analyse

2. Explain why a sample of distilled water was included in Sean's experiment.
3. Explain why Sean repeated the experiment three times each day on four separate days.
4. Suggest how Sean could improve the reliability and accuracy of his experiment.
5. Why did Sean use a column graph rather than another type of graph to present his results?

Evaluate and create

6. In your opinion, is Sean's conclusion valid? Give reasons for your answer.

Fully worked solutions and sample responses are available in your digital formats.

1.12 Using spreadsheets

LEARNING INTENTION

At the end of this subtopic you will be able to use a spreadsheet to record, graph and analyse data.

1.12.1 The advantages of spreadsheets

A spreadsheet is a computer program that can be used to organise data into columns and rows. Once the data are entered, mathematical calculations, such as adding, multiplying and averaging, can be carried out easily using the spreadsheet functions.

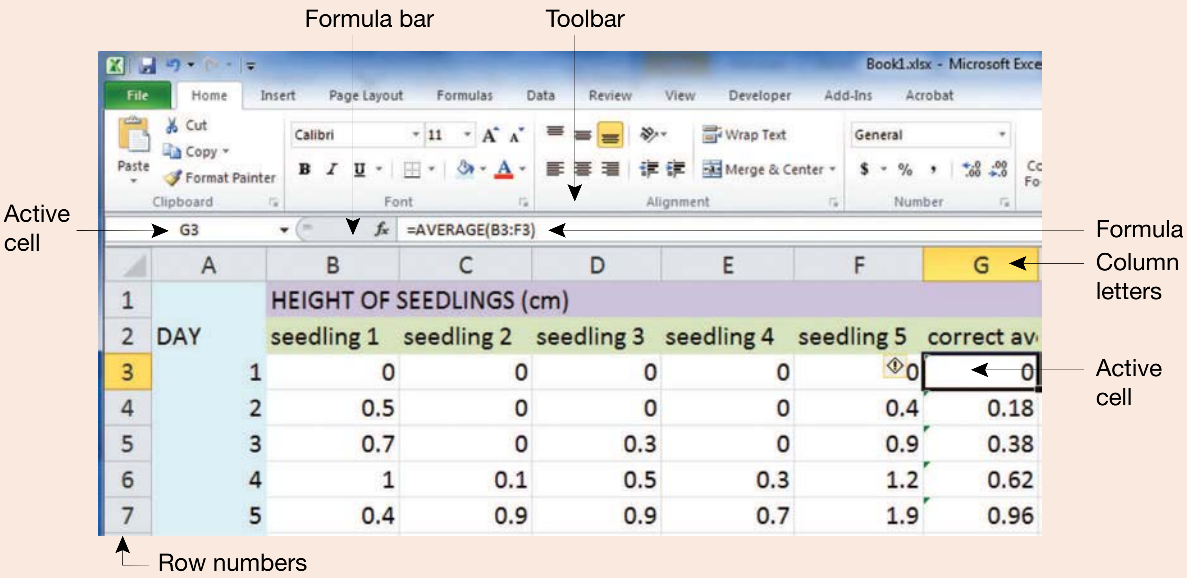
Spreadsheets have many advantages over handwritten or word-processed results. For example, with spreadsheets you can:
- make calculations quickly and accurately
- change data or fix mistakes without redoing the whole spreadsheet
- use the spreadsheet's charting function to present your results in graphic form.

1.12.2 Elements of a spreadsheet

Although there are a number of spreadsheet programs available, they all have the same basic features and layout, as shown in example 1 below. The data shown are from a student research project about the different factors on the growth of bean plants.

ELEMENTS OF A SPREADSHEET: Example 1

- At the top of the spreadsheet are the toolbar and formula bar.
- A *row* is identified by a number; for example, ‘row 1’ or ‘row 2’.
- A *column* is identified by a letter; for example, ‘column A’ or ‘column B’.
- A *cell* is identified by its column and row address. For example, ‘cell G3’ refers to the cell formed by the intersection of column G with row 3. In this example, cell G3 is the active cell (shown by its heavy border). The active cell address and its contents (once data are entered) are shown to the left of the formula bar.
- A *range* is a block of cells. For example, ‘range C3:F4’ includes all the cells in columns C through to F and rows 3 through to 4.



1.12.3 Entering data into cells

You can enter different types of data into a cell:

- a number or value
- a label, that is, text (for titles and headings)
- a formula (an instruction to make a calculation).

Decide in which cell you want to insert the data (the active cell). Type the data in the cell and press ‘Enter’. To edit or change the data, simply highlight the cell and type in the new data — it will replace the old data when you press ‘Enter’. Example 2 that follows shows a spreadsheet in which data have been entered.

1.12.4 Creating formulae

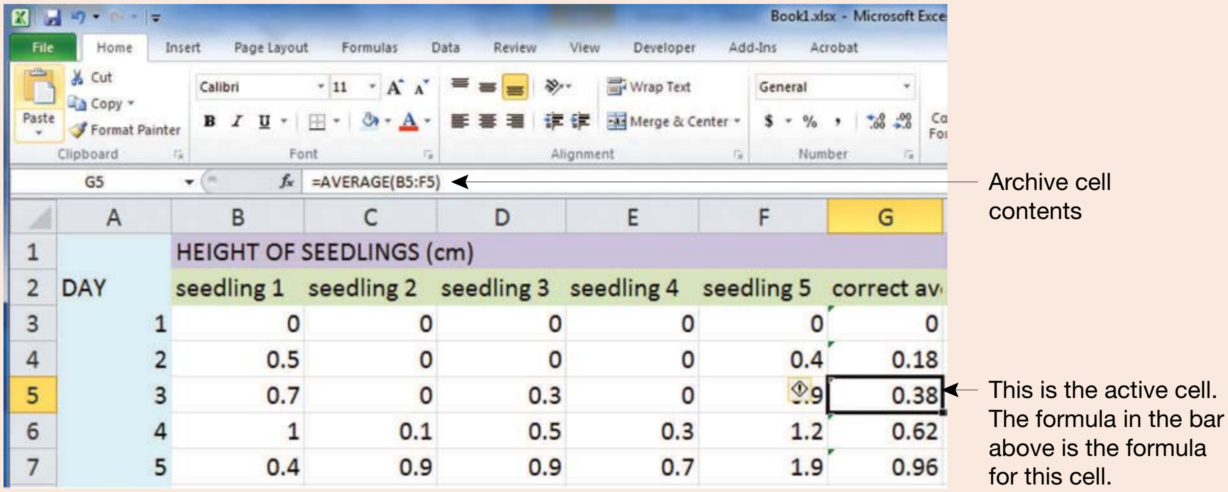
To create a formula, you need to start with a special character or symbol to indicate that you are keying in a formula rather than a label or value. This is usually one of the symbols =, @ or +, depending on the spreadsheet program. For example, a formula to add the contents of cell B1 to cell C1 would take one of the following forms: =B1+C1 or @B1+C1 or +B1+C1.

Once you have entered the formula in a cell, the result of the calculation, rather than the formula, will be shown. The formula can be seen in the status bar when the cell is active. (See example 2 that follows.) If you subsequently needed to change the values in B1 or C1, the spreadsheet will automatically use the formula to recalculate and show the new result.

> The symbols used for mathematical operations in spreadsheets are:
> + for addition
> – for subtraction
> * for multiplication
> / for division.

CREATING FORMULAE: Example 2

The spreadsheet in example 1 has been further developed. Formulae have now been entered to average the heights of the seedlings.



1.12.5 Using functions

Some common types of calculations are built into the spreadsheet, so that you don't always need to type out the full formulae. These are called **functions**. All functions have two parts: the name and a value (called the argument) that the function will operate on. The value is normally placed in parentheses, (), and can be written as a set of numbers or as a range (a block of cells). For example, a function to calculate the average of the amounts entered in cells B1, B2, B3 and B4 would be written: =AVERAGE(B1:B4).

This is also known as the mean of the values, which is calculated by adding up the values and dividing by how many there are.

The mode is the value that appears most in the chosen cells.

The median is the middle value when the cells are arranged in order of value.

Some of the common functions found in spreadsheets are shown in the table 1.5.

functions common type of calculation built into spreadsheets

TABLE 1.5 Common spreadsheet functions

Name	Application	Example	Result
AVERAGE	calculates the average of the argument values	=AVERAGE(1,2,3,4)	2.5
COUNT	counts the number of values in the argument	=COUNT(A3:A6)	4
MAX	returns the largest value in the argument	=MAX(1,9,5)	9
MIN	returns the smallest value in the argument	=MIN(1,9,5)	1
MODE	returns the most common value in the argument	=MODE(1,1,5,5,1)	1
MEDIAN	returns the median value of the argument values	=MEDIAN(1, 2, 3, 5, 6)	3
ROUND	rounds the argument to the number of decimal places specified	=ROUND(12.25,1)	12.3
SUM	calculates the sum of the values in the argument	=SUM(1,9,5)	15

1.12.6 Copying cells

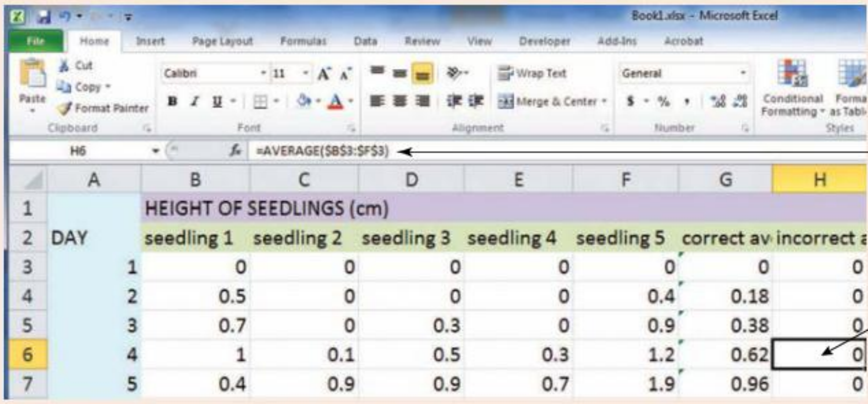
Spreadsheets have a command that allows you to copy a formula or value from one cell to another cell (or into a range of cells). This is usually found in the *Edit* menu (*Fill Down* or *Fill Right*). The way a formula is copied depends on whether the cell references use:

- **relative referencing**, which you use when you want the cell address in the formula to change according to the relative location of the cell that you have copied it to. Example 2 in section 1.7.4 uses relative referencing. The formula AVERAGE(B5:F5) in the active cell G5 was copied downwards, so that there was no need to type the formulae in the rest of the column. The formula in the next cell (G6) is therefore AVERAGE(B6:F6) and so on.
- **absolute referencing**, which you use when you want a cell address in the formula to be constant, no matter where it is copied to. Absolute referencing is denoted by the symbol $ placed in the cell address. For example, $B$3 (see example 3 below).

relative referencing used in a spreadsheet when the cell address in the formula is changed

absolute referencing used in a spreadsheet when a cell address in the formula remains constant, no matter where it is copied to

COPYING CELLS: Example 3



The formula has a $ sign in front of the cell coordinates, so that the coordinates do not adjust automatically as the row number changes.

The formula above is the formula for this cell in row 5.

1.12.7 Formatting cells

Investigate your spreadsheet program (most come with a tutorial) to learn how to use other useful features such as:

- adding and deleting rows or columns (useful if you have forgotten to include some calculations in your planning or decide you don't need some items)
- changing column widths (to show the full cell contents when the data are longer than the default column width) and changing row heights so that you can use larger font sizes for titles and headings
- inserting horizontal or vertical lines to improve the presentation of your spreadsheet
- changing cell formats to control how the data are to be displayed, such as using different fonts and character styles (underlining, bold, italic).

You can also format numeric values in a variety of ways. For example, the *Fixed* or *Number* format will display values to the number of specified decimal places. The *Percent* format will display values as a percentage, to the number of specified decimal places.

Once you have keyed in your data and included any necessary calculations, print out your spreadsheet and save it to a disk so that you can store the document and use it later.

1.12.8 Spreadsheet graphics

The three main types of graphs — pie, bar and line graphs — can usually be produced by a spreadsheet. It means that you can easily display your results graphically, but you still need to decide which is the most appropriate type of graph for your data.

The first step in producing a spreadsheet graph is to select the block of the cells that contains the data to be graphed. Use the spreadsheet's charting function, which usually brings up a window where you can indicate the type of graph, and add title and label details. When you are satisfied with the result, you can display and print out your graph.

on Resources

eWorkbooks Spreadsheeting and graphing (ewbk-5305)
Calculating using a spreadsheet (ewbk-5307)

assess on Additional automatically marked question sets

1.12 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Question 1	Questions 2, 3	Question 4

Remember and understand

1. Look at the section of a spreadsheet presented below and answer the following questions:

H6 fx =AVERAGE($B$3:$F$3)

A	B	C	D	E	F	G	H
	HEIGHT OF SEEDLINGS (cm)						
DAY	seedling 1	seedling 2	seedling 3	seedling 4	seedling 5	correct av	incorrect a
1	0	0	0	0	0	0	0
2	0.5	0	0	0	0.4	0.18	0
3	0.7	0	0.3	0	0.9	0.38	0

a. What does cell G3 contain?
b. Does cell E2 contain a value or a label?
c. If the formula in cell G4 is AVERAGE(B4:F4), what would the formula be in cells G5 and G6?

Apply and analyse

2. The following table shows the results of an experiment that tested the amount of time taken for eucalyptus oils and other substances (0.1 mL of each) to evaporate at a constant temperature. The experiment was done twice.

TABLE Time taken to evaporate different substances

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

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

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

TABLE Distance and speed travelled in 3-second intervals

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

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

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

b. What was Jesse's average speed over the total time?

Evaluate and create

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

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

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

a. Enter the data into a spreadsheet and create a graph to display these results.
b. Create formulae to work out the average carbon monoxide and carbon dioxide emissions for:
   i. cars manufactured up to 1985
   ii. cars manufactured from 1987 onwards.
c. Car manufacturers were required to install catalytic converters in cars made after 1986. Catalytic converters cut down carbon monoxide emissions by converting some of the carbon monoxide to carbon dioxide. What can you conclude from this data about the success of catalytic converters?

Fully worked solutions and sample responses are available in your digital formats.

1.13 Using data loggers and databases

LEARNING INTENTION

At the end of this subtopic you will be able to use a data logger, analyse the data generated and how to create a simple database.

1.13.1 The data logger

A data logger is a device that stores a large number of pieces of information (data) sent to it by sensors attached to it. The data logger can transfer this data to another device, such as a graphing calculator or, more commonly, a computer, which can use data logger software or a spreadsheet program to manipulate the data (see section 1.12.1). Usually the computer or calculator graphs the collected data, and we can use these graphs to see patterns and trends easily.

When can a data logger be used?

Data loggers are particularly useful whenever an experiment requires several successive measurements. Sometimes, these measurements will take place over several hours or days — such as when measuring the way air pressure varies with the weather. Sometimes, many measurements must be taken over a short time interval — such as when measuring changes in air pressure as sound waves pass by. Data loggers are very flexible and can help scientists gather and analyse data for these types of experiments, as well as many others. As an example of how a data logger might help you in your scientific investigations, let's consider the following common exothermic and endothermic experiments.

CASE STUDY: Using a data logger to investigate exothermic and endothermic processes

In an experiment, we investigate temperature changes in chemical processes. In part 1, we observe the reaction of magnesium metal with dilute hydrochloric acid and, in part 2, citric acid and baking soda. In addition to the laboratory equipment required for this experiment, including safety glasses, we will need a data logger with a temperature sensor attached to it. The data logger will need to be attached to a computer on which the data logger software has been installed.

Part 1: Magnesium in hydrochloric acid

Active metals react with dilute acids to give off hydrogen gas and leave behind a salt that usually stays dissolved in the water in which the acid was dissolved. To investigate whether heat is given off or taken in during the reaction, we will need the equipment shown in figure 1.28. We could use a test tube or a beaker (as shown in the photo). If we use a beaker, we will have to use more acid; in this case, we will use 100 mL of 0.5 mol/L hydrochloric acid.

FIGURE 1.28 The equipment required for *Part 1: Magnesium in hydrochloric acid*

We now set up the data logger to collect data for the length of time that we need and at the rate we require. The data logger itself or its software allows us to do this. Figure 1.29 shows the data logger being set to collect temperature data for 200 seconds at the rate of once per second. Now it's a simple matter of putting the temperature sensor in the dilute acid, pressing the button on the data logger to start data collection and adding the magnesium.

FIGURE 1.29 Set the data logger to take temperature data for 200 seconds at the rate of once per second.

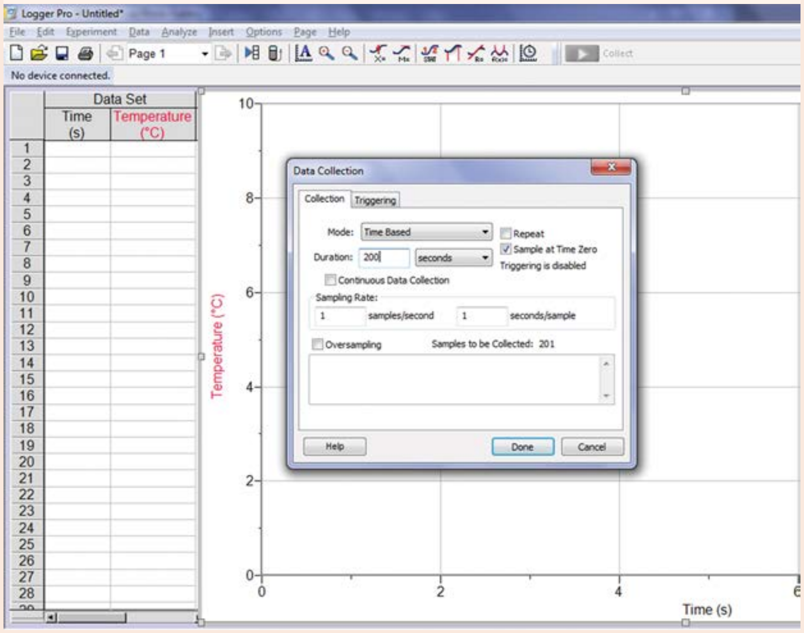
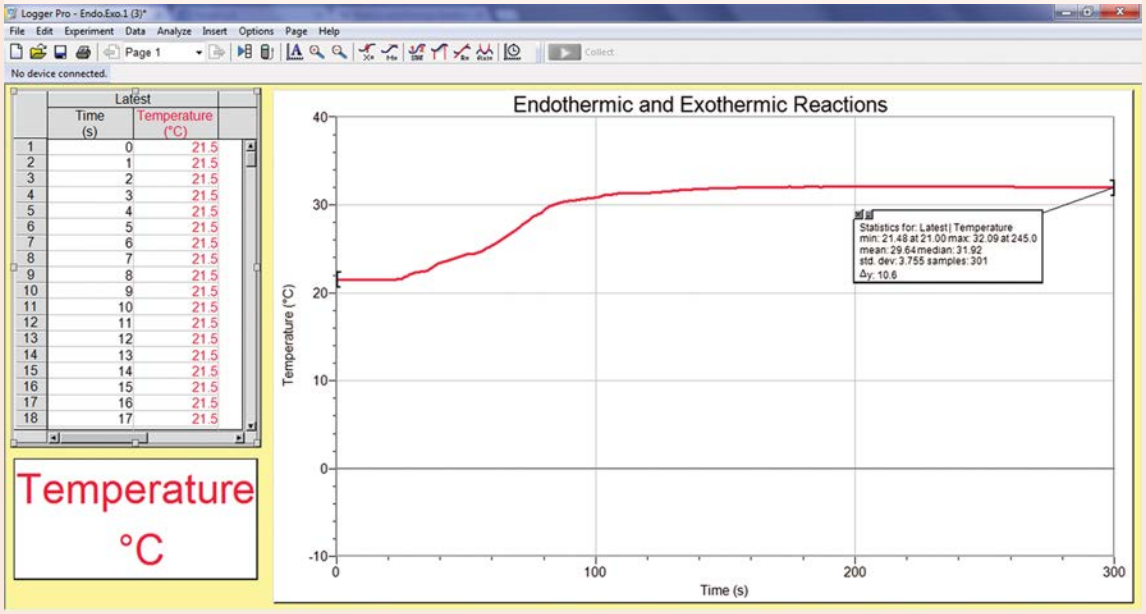


FIGURE 1.30 Place the temperature sensor into the beaker of dilute acid and add the magnesium.

The reaction proceeds for 200 seconds and the sensor sends a temperature measurement every second to the data logger. When the selected time has passed (that is, after 200 seconds), the data logger sends all the data to the computer, which (via the software) displays it as a graph, as shown in figure 1.31.

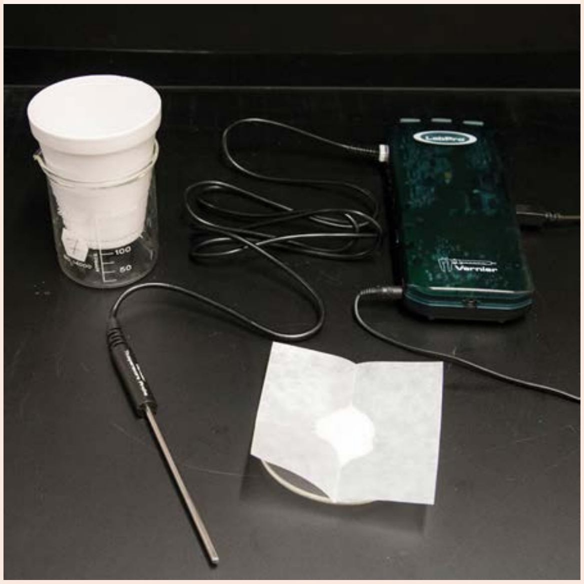
FIGURE 1.31 Graphed data for part 1 of the *exothermic and endothermic processes* experiment



Part 2: Citric acid and baking soda

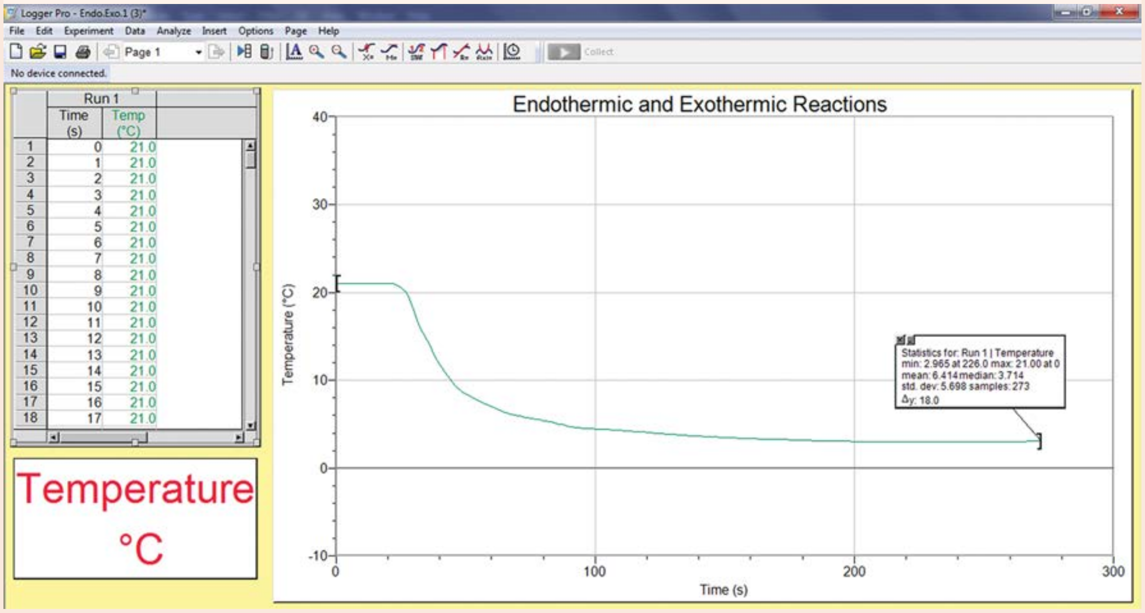
For this part of the experiment, we will need baking soda, citric acid, a beaker, a foam cup, other necessary laboratory equipment such as safety glasses, as well as a data logger and temperature sensor. We will use 30 mL of citric acid and 10 g of baking soda. These items are shown in the photograph in figure 1.32.

FIGURE 1.32 The equipment required for *Part 2: Citric acid and baking soda*



Once again, we set the run time to 200 seconds and the data collection rate to once per second. We insert the temperature sensor into the acid, press a button on the data logger to start data collection and then add the baking soda to the acid. The data logger collects the data, which the computer software automatically graphs after completion of the run, as shown in figure 1.33.

FIGURE 1.33 Graphed data for part 2 of the *exothermic and endothermic processes* experiment



This investigation is summarised in the following investigation box.

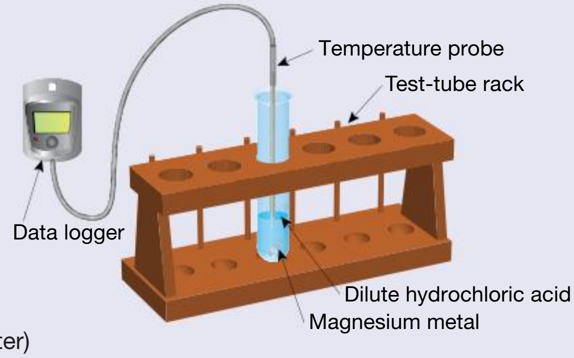
INVESTIGATION USING A DATA LOGGER

Exothermic and endothermic processes

Part 1 is for Teacher Demonstration only

Materials

- safety glasses
- bench mat
- 4 large test tubes and test-tube rack
- 10 mL measuring cylinder
- balance
- thermometer (–10 °C to 110 °C)
- stirring rod
- magnesium ribbon
- sandpaper
- 0.5 mol/L hydrochloric acid
- 30 mL citric acid solution (10 g dissolved in 100 mL water)
- 10 g baking soda (dissolved in 100 mL water)



Method

Part 1: Magnesium in hydrochloric acid

1. Pour 10 mL of 0.5 mol/L hydrochloric acid into a test tube in a test-tube rack. Place a thermometer or probe in the test tube and allow it to come to a constant temperature. Record the temperature of the solution.
2. Clean a 10 cm piece of magnesium ribbon using the sandpaper until it is shiny on both sides. Coil the magnesium ribbon and place it into the test tube of hydrochloric acid.
3. Observe the temperature of the solution as the magnesium reacts with the hydrochloric acid. Record the final temperature of this solution.

Part 2: Citric acid and baking soda

4. Pour 10 mL of citric acid solution into a test tube in a test-tube rack. Place a thermometer in the water in the test tube and allow it to come to a constant temperature. Record the temperature of the water.
5. Use a balance to weigh 3 g of baking soda; add it to the water in the test tube and stir gently.
6. Observe the temperature of the solution as the baking soda dissolves in the water. Record the final temperature of this solution.

1.13.2 Using databases

Databases are simply information or data arranged in one or more tables. We use databases every day; for example, when we look up information in the index of a book.

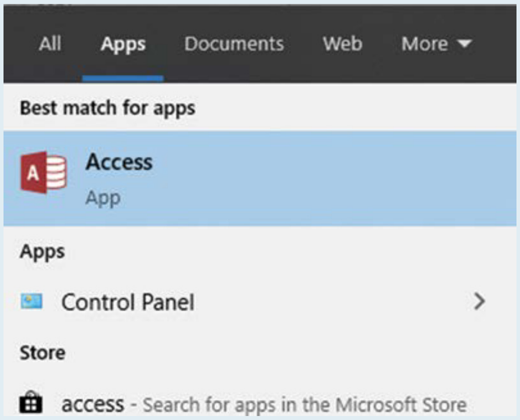
An electronic database is one of the most powerful computer applications and is an important tool for a business, an organisation or a scientist. A database's design is crucial to its usefulness, so a database must be designed with ease of searching uppermost in mind. The most common is Microsoft Access. In the activity that follows you will create a database using some of the features of Microsoft Access.

ACTIVITY: Creating a database of Nobel Prize winners

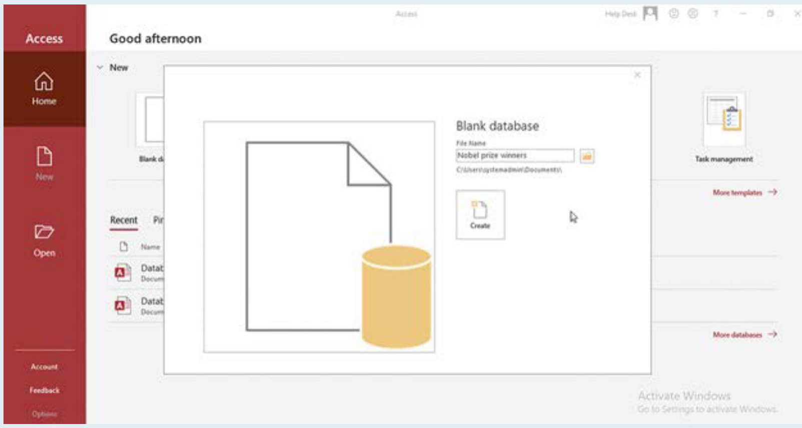
Before creating your database, you will need to find some information to put in it. This is best done as a class activity with each student in the class researching one or two Nobel Prize winners.

- Each student in the class should research one or two different Nobel Prize winners. Choose people who have won a Nobel Prize for work in the categories of Chemistry, Physics or Medicine.

- For each prize winner, collect the data listed below. Ideally the data should be written on cards that can be passed around the class, or they could be displayed in large writing on large sheets of paper around the room.
  - First name
  - Last name
  - Country of birth
  - Year of birth
  - Category of award (such as Chemistry, Physics or Medicine)
  - Organisation (where the person worked)
  - Nobel Prize awarded for (one sentence or phrase that outlines the work for which the scientist received the award)
  - Share received (if the award was shared by a group of people)
- Microsoft Access software is commonly used to create databases. The following instructions may not be the same as your edition of this software. Other editions are similar to use but the screens are not exactly the same. You can start Access by clicking on the search bar of your PC and then the Access icon is shown.

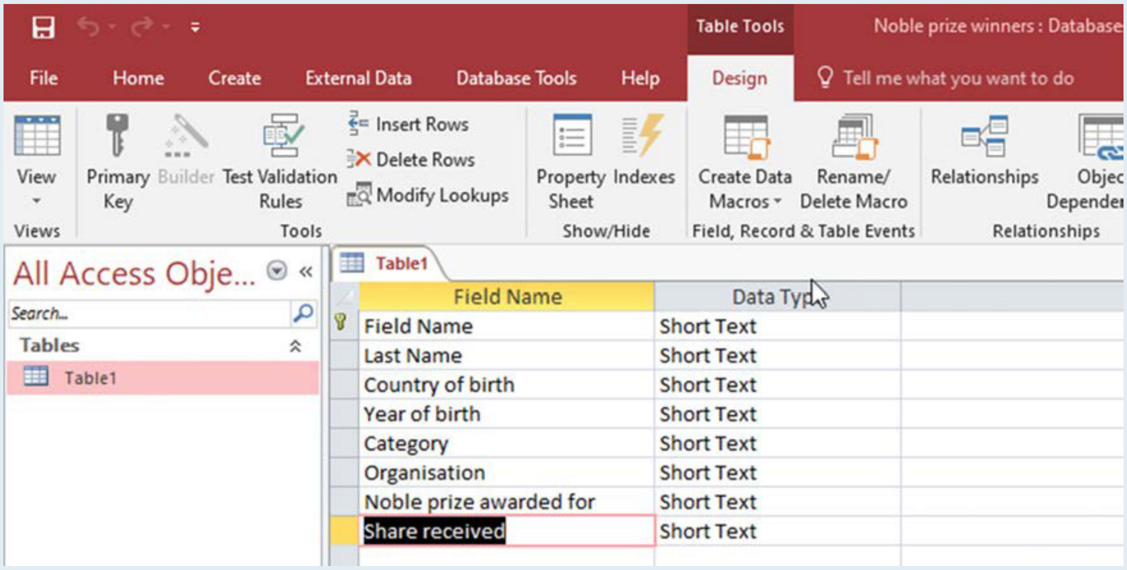


- When you open the software, a list of options will appear along the top of the screen. Choose the option *Blank database*. A dialog box will appear for you to enter a name for your database and click *Create*.

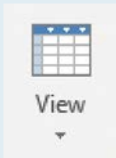


- A *Table* window will open. Ensure you are in *Design* view by clicking on the drop-down *View* options under *File*. This will prompt you to Save the table. Give the table a suitable name (such as ‘Table 1’) and click *OK*. Now you can enter field names, which are the column headings for the database.

Enter the field names as shown in the next figure. You will note that, by default, the data type may be *Autonumber*. Use the drop-down menu to choose *Short text*.



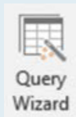
- Now that you have designed the database, it is time to change to datasheet view. Click on the Datasheet view button left-hand corner of the screen. You will be prompted to save the table. Give the table a suitable name (such as 'Table 1') and click *OK*.

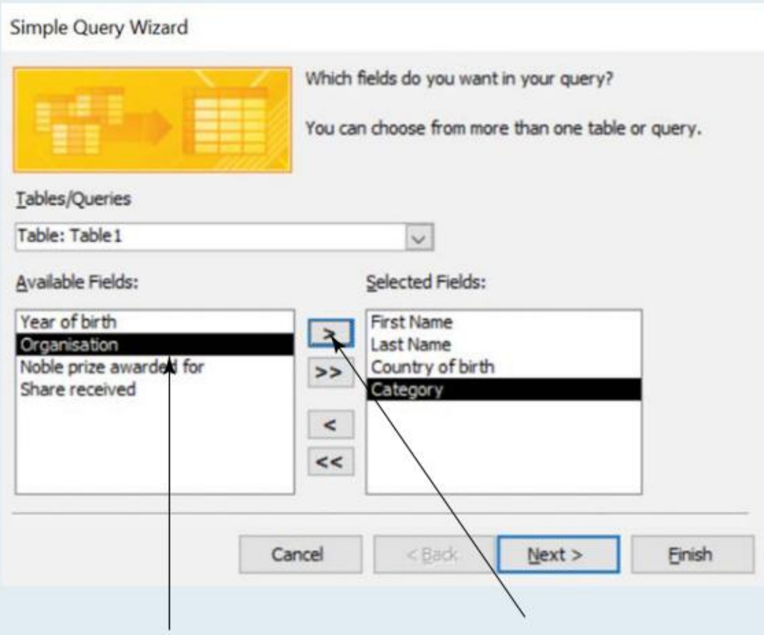


- Enter the data that you and your classmates found into the table. You can do this manually or import data from a spreadsheet or text file by using the *External data* tab on the ribbon. When you have done this, save your database.

The great thing about databases is that they allow you to search for data that match particular criteria. This is called running a *query*. We are going to create a query to find all the Nobel Prize winners in our database who were awarded a prize for Medicine and were born in the United States.

- Make sure you are in datasheet view. Click *Create* on the ribbon. Select *Query wizard, then Simple Query Wizard* and then click *OK*. The fields in your table will be displayed; click on the ones you want to appear in the query then click on the single arrow to move them into the *Selected Fields* box. Select the following fields: first name, last name, country of birth and category. When you have done this, click *Next*. In the next dialog box, enter a name for your query, select *Modify the query design* and click on *Finish*.

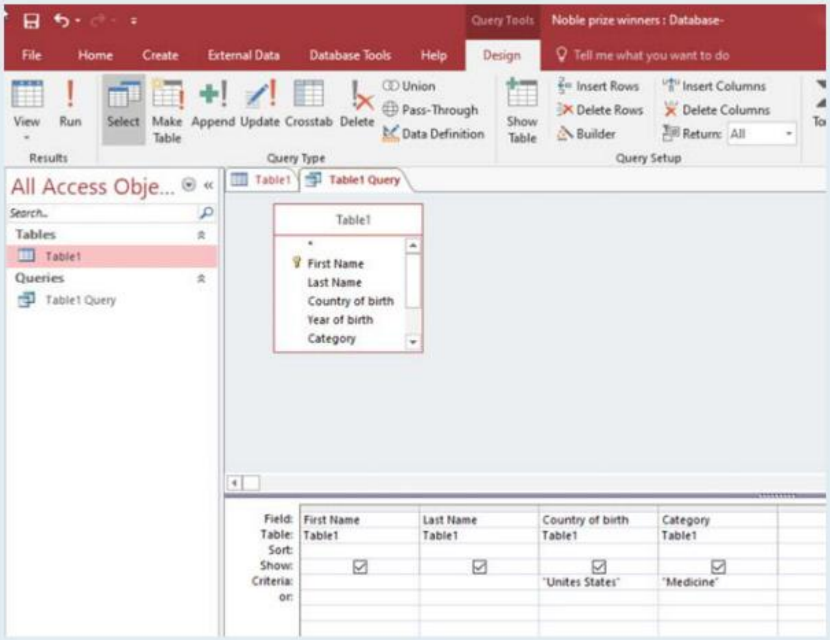




Click on a field to select it.

Click on the single arrow to move the field into the Selected Fields box.

- The screen below will appear. Now enter the criteria you want the query to look for in the appropriate boxes. In the Category column, type 'Medicine' (without the quotation marks) in the *Criteria* row. In the Country of birth column, type 'United States' in the *Criteria* row. Quotation marks will automatically appear when you press [Enter]. This is shown below.



- Now click on the Run button in the toolbar near the top of the screen. The query will run and a table displaying the Nobel Prize winners that match your criteria will appear.
- Create a new query to display the Nobel Prize winners who won the Nobel Prize for Physics and were born in England.

on Resources

assesson Additional automatically marked question sets

1.13 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Describe a data logger and what it does in a way that a Year 7 student would understand.
2. a. List the advantages of using a data logger over taking the measurements manually.
   b. Describe an experiment in which using a data logger provides an advantage over manual data collection.
3. Acids are corrosive substances; they react with most metals, such as the magnesium in part 1 of the experiment. The temperature probe is made of metal but it doesn't react with acids. What sort of metal is it and what protects it from the acid?

Apply and analyse

4. Sensors are the devices that take the measurements that the data logger collects. Think of scientific investigations that could use data collected by sensors that measure:
   a. electric current
   b. acidity of solutions
   c. concentration of carbon dioxide in the air
   d. total dissolved solids (salt content)
   e. light intensity.

Evaluate and create

5. Look back at *Part 1: Magnesium in hydrochloric acid* in the case study.
   a. Write a word equation for the reaction that occurs.
   b. Look at the graph of temperature vs time for this reaction. Was the reaction exothermic or endothermic? How do you know?
   c. How long after data collection began was the magnesium ribbon added to the acid? How do you know?
   d. How did the person who conducted this investigation know when the reaction was complete?
   e. What was the initial temperature of the dilute acid used in this experiment?
   f. What change in temperature did this reaction cause in the liquid in the beaker?
6. Look at the graph of the collected data produced by the computer for *Part 2: Citric acid and baking soda*.
   a. What was the temperature of the acid at the start of the experiment?
   b. What was the lowest temperature that the solution of citric acid and baking soda reached? How long after first adding the baking soda did this occur?
   c. Is dissolving baking soda in citric acid an exothermic or endothermic process? How do you know?

Fully worked solutions and sample responses are available in your digital formats.

1.14 Thinking tools — Visual thinking tools

1.14.1 Tell me

There are so many different ways to see and share what is happening inside your brain. Here are some tools that can be used to make your thinking visible so that you can share and discuss it with others.

Like a builder, it is important for you to use the right tool to get the job done.

- **Storyboards**, **flow charts**, **timelines**, **fishbone diagrams** and **cycle maps** are useful tools to order or sequence your thoughts (figure 1.34).
- **Matrixes**, **SWOT analysis charts**, **Venn diagrams**, and **bubble maps** are useful when you want to analyse or compare your thoughts (figure 1.35).
- **Priority grids**, **target maps**, **continuums** or **pie charts** can be used to quantify or rank ideas (figure 1.36).
- **Concept maps**, **PMI charts** and **mind maps** help you to visualise or reflect on an idea.

There are also times when combinations of these tools can help you to use your brain and time more effectively.

1.14.2 Show me

The following diagrams show various ways to organise your thinking. The tool you choose to use depends on what topics, ideas, events or process you are examining.

These tools are explored in more detail in the following topics:

- Topic 3: Priority grids and matrixes
- Topic 4: Cycle maps and relations diagrams
- Topic 5: SWOT analysis
- Topic 6: Concept maps and plus, minus, interesting charts
- Topic 7: Matrixes and plus, minus, interesting charts
- Topic 8: Double bubble maps
- Topic 9: Plus, minus, interesting charts
- Topic 10: Flow charts

storyboard a visual thinking tool that summarises a sequence of scenes

flow chart a visual thinking tool that shows a sequence of events or steps in a process

timeline a visual thinking tool that shows a sequence of events by date

fishbone diagram a visual thinking tool that analyses and compares by breaking an event into smaller causes to show why something has happened

cycle map a visual thinking tool that describes a cyclical process

matrix a visual thinking tool that organises, analyses and compares using a grid

SWOT analysis chart a visual thinking tool that helps classify or organise thoughts according to strengths, weaknesses, opportunities and threats

Venn diagram a visual thinking tool that analyses and compares by showing common features and different features

bubble map a visual thinking tool that organises, analyses and compares by showing common and different features of topics

priority grid a visual thinking tool that quantifies and ranks based on two criteria

target map a visual thinking tool that quantifies and ranks based on relevance

continuum a visual thinking tool that shows extremes of an idea or where people stand on a particular idea or issue

pie chart a diagram using sectors of a circle to compare the sizes of parts making up a whole quantity

concept map a visual thinking tool that shows the connections between ideas

PMI chart visual thinking tool that classifies using positive, negative and interesting features

mind map a visual thinking tool with a central idea and associated ideas arranged around it

FIGURE 1.34 Thinking tools that help you order or sequence your thoughts

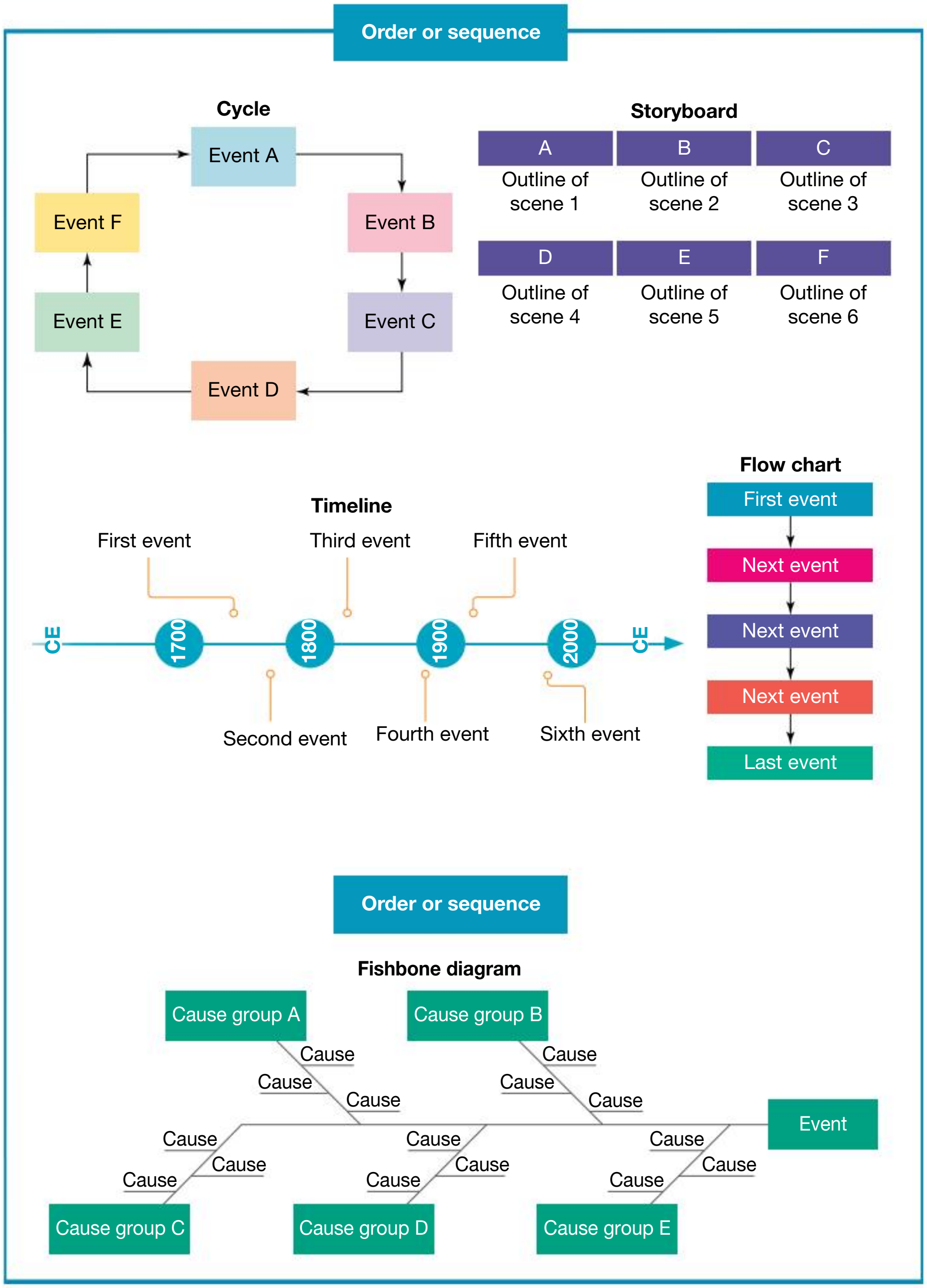


FIGURE 1.35 Thinking tools that help you analyse or compare your thoughts

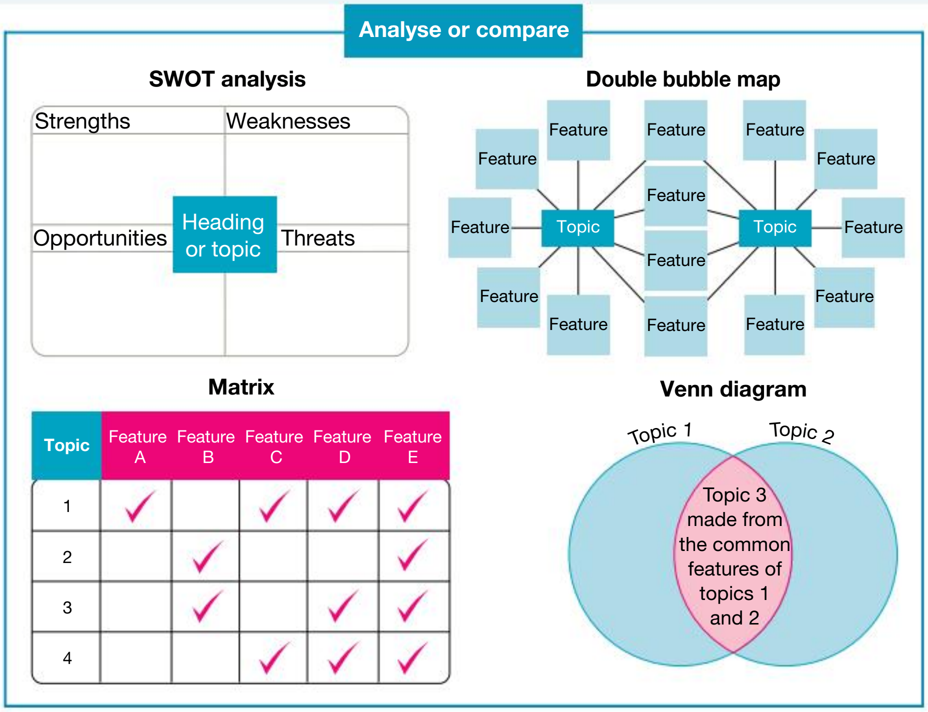


FIGURE 1.36 Thinking tools that help you quantify or rank your thoughts

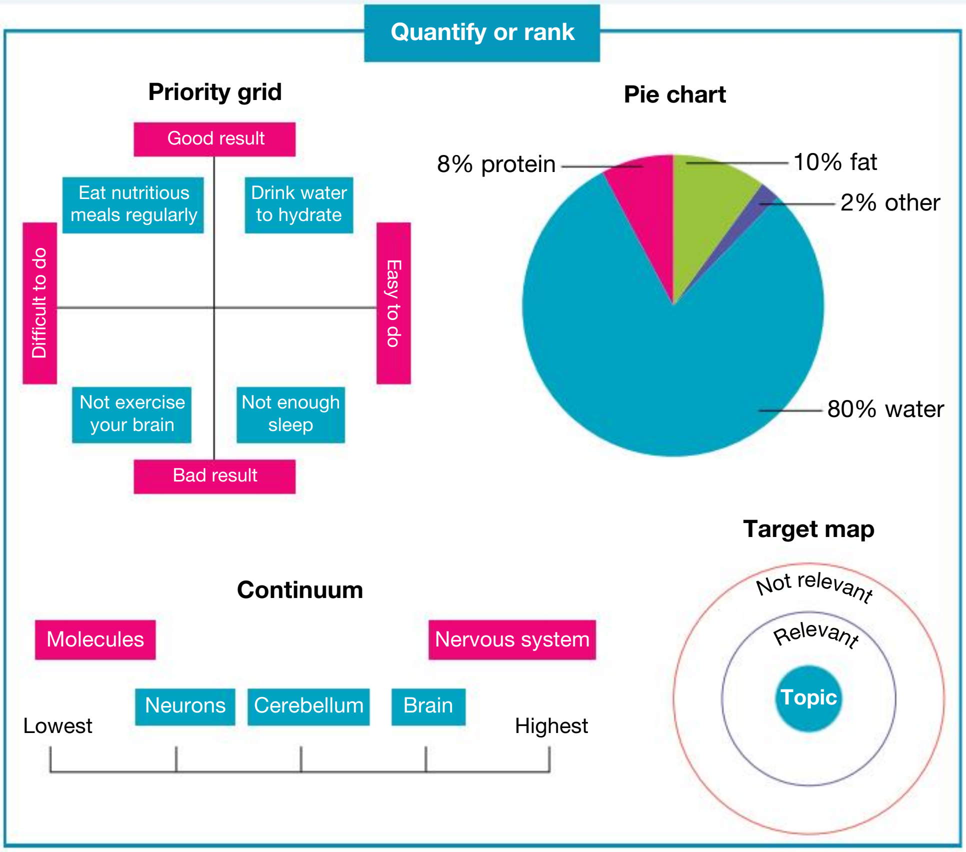
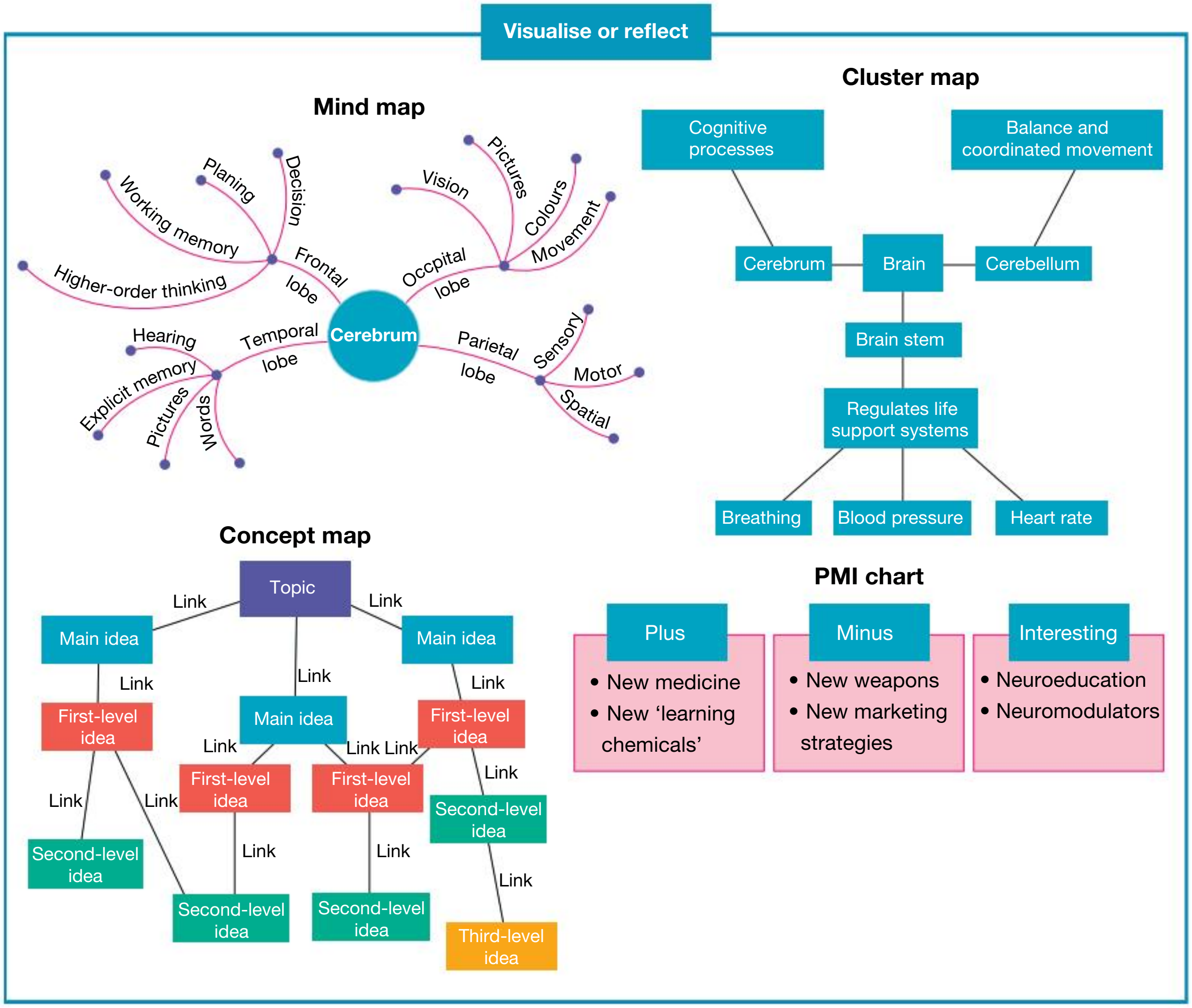


FIGURE 1.37 Thinking tools that help you visualise or reflect on your thoughts



1.14.3 Let me do it

1.14 ACTIVITIES

1. State the types of visual thinking tools that are best suited to:
   a. quantifying or ranking ideas
   b. visualising or reflecting
   c. analysing or comparing
   d. ordering or sequencing.
2. Use a visual thinking tool to summarise key or interesting points from each subtopic within this chapter.

Fully worked solutions and sample responses are available in your digital formats.

1.15 Review

Access your topic review eWorkbooks

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-5309	ewbk-5311	ewbk-5313

on Resources

1.15.1 Summary

Scientists through the ages

- The earliest scientists were the ancient Greek philosophers who used logic and conducted thought experiments.
- The scientific revolution started when Galileo Galilei invented the telescope and used it to propose new theories about the planets and stars. His work formed the basis of many other influential scientists' discoveries.
- Isaac Newton furthered our understanding of the universe by creating the theory of gravity, which explained the movement of the planets around the Sun.
- Modern day scientists work more collaboratively than past scientists and can therefore conduct research more efficiently.

Accidents and observations

- Many of the great scientific discoveries came about by accident.
- Luigi Galvani created the first electric cell by accident whilst dissecting a frog.
- X-rays were discovered when German physicist Wilhelm Röntgen noticed that a photographic plate he had left sitting around glowed when high voltage electricity passed through a glass tube.
- Penicillin was discovered when a spot of mould on a dish that was growing bacteria prevented the bacteria from growing near it.

A question of ethics

- Ethics is the system of moral principles on the basis of which people, communities and nations make decisions about what is right or wrong.
- Ethics affects the way experiments are conducted, types of research and practices within the scientific community.
- Animal testing Is not allowed in Australia and most places around the world.
- The ethics of any new drug production should be examined to balance profitability and the benefit to the community.
- Genetic modification involves moving genes from one plant to another, to enable the plants to have certain characteristics.

Your own investigation

- The scientific method provides a template that allows scientific research to be communicated worldwide.
- A hypothesis is a tentative, testable and falsifiable statement for an observed phenomenon that acts as a prediction for the investigation.
- The first step in the scientific method is to develop a valid question.
- A logbook provides a complete record of your investigations; it should be dated and contain notes, results, diagrams, evidence, problems, and evaluations and drafts of your conclusions.
- There are three types of variables:
  - Independent variables are deliberately changed in an experiment.
  - Dependent variables are the variables that are measured in an experiment.
  - Controlled variables are kept constant throughout an experiment.

- The process of controlling variables is also known as fair testing.
- Scientific experiments are valid if they measure what they set out to measure. For example, if you were investigating the growth rate of plants and you measured the number of plants that germinated over a period of time, your experiment would be invalid as it is not measuring the growth rate.
- Precision is a measure of how close together your measurements are across multiple trials.
- Accuracy is a measure of how close your results are to known values.
- There are two types of data:
  - Quantitative data is data that is numerical
  - Qualitative data is expressed in words.
- Data is much easier to understand when it is presented graphically. Types of graphs include scatterplots, line graphs, bar/column graphs, histograms, pie charts and divided bar charts.
- On a line graph, the independent variable is shown on the x-axis, and the dependent variable on the y-axis.
- A scientific report should contain an abstract, introduction, aim, materials, method, results, discussion, conclusion, bibliography and any acknowledgements.
- Valid investigations are able to be replicated in different circumstances but with the same conditions.
- Surveys should have a large sample size, the questions should be clear, and a control group should be used if necessary.

Case study

- Sean's investigation into the turbidity (cloudiness) of water sources near his home show how an investigation can be completed, from start to finish.

Using spreadsheets

- Spreadsheets can be used to analyse or graph data automatically. This can save time and reduce errors.
- Spreadsheets contain many functions that can be used to extract information from data or perform calculations automatically. Examples include average, count, max, min, round and sum.

Using data loggers and databases

- Data loggers are instruments that record data digitally. This reduces the human error in their measurements, making them a reliable source of data.
- Some data loggers are also able to plot the data they record to provide accurate graphs automatically.
- Databases are information or data arranged in one or more tables. Spreadsheets can be used to draw conclusions about the data in a database.

1.15.2 Key terms

absolute referencing used in a spreadsheet when a cell address in the formula remains constant, no matter where it is copied to
accurate refers to how close an experimental measurement is to a known value
bibliography list of references and sources at the end of a scientific report
blog a personal website or web page where an individual can upload documents, diagrams, photos and short videos, add links to other sites and invite other people to post comments
bubble map a visual thinking tool that organises, analyses and compares by showing common and different features of topics
calibration the process whereby a measuring instrument is restored to accuracy
concept map a visual thinking tool that shows the connections between ideas
continuum a visual thinking tool that shows extremes of an idea or where people stand on a particular idea or issue
control an experimental set-up in which the independent variable is not applied that is used to ensure that the result is due to the variable and nothing else
controlled variables the conditions that must be kept the same throughout an experiment
cycle map a visual thinking tool that describes a cyclical process

dependent variable a variable that is expected to change when the independent variable is changed. The dependent variable is observed or measured during the experiment.
ethics the system of moral principles on the basis of which people, communities and nations make decisions about what is right or wrong
fair testing a method for determining an answer to a problem without favouring any particular outcome; another name for a controlled experiment
fishbone diagram a visual thinking tool that analyses and compares by breaking an event into smaller causes to show why something has happened
flow chart a visual thinking tool that shows a sequence of events or steps in a process
functions common type of calculation built into spreadsheets
galvanometer an instrument used to measure small electric currents; named after Luigi Galvani
genetic modification (GM) the technique of modifying the genetic structure of organisms making it possible to design organisms that have certain characteristics
independent variable a variable that is deliberately changed during an experiment
logbook a complete record of an investigation from the time a search for a topic is started
lysozyme a chemical (enzyme) in human teardrops able to kill some types of bacteria as part of your body's natural defence
matrix a visual thinking tool that organises, analyses and compares using a grid
mind map a visual thinking tool with a central idea and associated ideas arranged around it
penicillin a powerful antibiotic substance found in moulds of the genus *Penicillium* that kills many disease-causing bacteria
pie chart a diagram using sectors of a circle to compare the sizes of parts making up a whole quantity
PMI chart visual thinking tool that classifies using positive, negative and interesting features
precise refers to how close multiple measurements of the same investigation are to each other
priority grid a visual thinking tool that quantifies and ranks based on two criteria
qualitative data (or categorical data) data expressed in words
quantitative data (or numerical data) data that can be precisely measured and have values that are expressed in numbers
relative referencing used in a spreadsheet when the cell address in the formula is changed
reliable data data that is able to be replicated in different circumstances but the same conditions
scientific method a systematic and logical process of investigation to test hypotheses and answer questions based on data or experimental observations
storyboard a visual thinking tool that summarises a sequence of scenes
SWOT analysis chart a visual thinking tool that helps classify or organise thoughts according to strengths, weaknesses, opportunities and threats
target map a visual thinking tool that quantifies and ranks based on relevance
timeline a visual thinking tool that shows a sequence of events by date
valid sound or true. A valid conclusion can be supported by other scientific investigations.
variable quantity or condition that can be changed, kept the same or measured during an experiment
Venn diagram a visual thinking tool that analyses and compares by showing common features and different features

on Resources

eWorkbooks	Study checklist (ewbk-5315) Literacy builder (ewbk-5316) Crossword (ewbk-5318) Word search (ewbk-5320)
Digital document	Key terms glossary (doc-35019)

1.15 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Match the words in the list below with their meanings.

Words	Meanings
a. Conclusion	A. Concerns that deal with what is morally right or wrong
b. Abstract	B. The variable that is deliberately changed in an experiment
c. Discussion	C. The part of a journal article where a brief overview of the article is given
d. Results	D. A list of steps to follow in an experiment
e. Hypothesis	E. The answer to the aim or the problem
f. Ethical considerations	F. A list of equipment needed for the experiment
g. Independent variable	G. The variable that is measured in an experiment
h. Dependent variable	H. States what was seen or measured during an experiment. May be presented in the form of a table or graph.
I. Method	i. A sensible guess to answer a problem
j. Apparatus	J. The part of a report where problems with the experiment and suggestions for improvements are discussed

2. List some of the factors affecting the decision about whether money is spent on finding a cure for a particular disease.

Apply and analyse

3. Should farmers be allowed to plant the type of crop they believe produces the best yield, irrespective of whether others object to the manner in which the crop was bred?
4. In the film *Super Size Me*, the film-maker Morgan Spurlock gains weight and suffers health problems after thirty days of eating from only one fast-food chain. The film suggests that this fast food is unhealthy.
   a. What factors should be taken into account when considering the effects of a fast-food diet compared with a broader eating pattern?
   b. Was this a controlled experiment?
   c. Is Spurlock's argument valid? Explain your answer.
   d. What type of arguments could the fast-food chain put forward in response to the film *Super Size Me*?

Evaluate and create

5. Gemina and Habib wanted to investigate whether the type of surface affects how high a ball bounces. Habib thought the ball would probably bounce the highest off a concrete floor. They dropped tennis balls from different heights onto a concrete floor, a wooden floor and carpet. Their results are shown in the table provided.

TABLE Height of ball bounce off different surfaces

	Average height of bounce (cm)		
Distance ball dropped (cm)	**Concrete**	**Wood**	**Carpet**
25	22	14	8
50	46	34	18
75	70	50	26
100	94	66	34
125	X	85	Z
150	128	94	48
175	129	Y	50
200	130	100	51

a. Write a hypothesis for this experiment.
b. Construct a line graph of Gemina and Habib's results.
c. Use your graph to estimate the values X, Y and Z.
d. Identify two variables that had to be kept constant in this experiment.
e. Identify two trends in the results.
f. Do the results support the hypothesis you wrote?
g. Predict how high the tennis ball would bounce off each floor if it was dropped from a height of 225 cm.

6. Miranda wanted to test the following hypothesis: Hot soapy water washes out tomato sauce stains better than cold soapy water.

TABLE Observations of washing in different water temperatures

Water temperature (°C)	Observations
20	Dark stain left after washing
40	Faint stain left after washing
60	No stain left after washing
80	No stain left after washing

a. List the equipment she will need.
b. Identify the independent and dependent variables in this investigation.
c. List the variables that will need to be controlled.
d. Outline a method that could be used to test the hypothesis.
e. Write a conclusion based on Miranda's results.

Fully worked solutions and sample responses are available in your digital formats.

on Resources

eWorkbook Reflection (ewbk-3038)

teachon

Test maker
Create customised assessments from our extensive range of questions, including teacher-quarantined questions. Access the assignments section in learnON to begin creating and assigning assessments to students.

RESOURCE SUMMARY

on Resources

Below is a full list of **rich resources** available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

1.1 Overview

eWorkbooks
- Topic 1 eWorkbook (ewbk-5276)
- Student learning matrix (ewbk-5278)
- Starter activity (ewbk-5279)

Video eLesson
- Australia's top scientists (eles-1079)

Weblink
- The Australian Academy of Science

1.5 Your own investigation

eWorkbooks
- Setting up a logbook (ewbk-5281)
- Variables and controls (ewbk-5283)
- Investigating (ewbk-5285)
- Organising and evaluating results (ewbk-5287)
- Drawing conclusions (ewbk-5289)
- Summarising (ewbk-5291)
- Evaluating media reports (ewbk-5293)

1.6 SkillBuilder — Writing an aim and forming a hypothesis

eWorkbook
- SkillBuilder — Writing an aim and forming a hypothesis (ewbk-5295)

Video eLesson
- Writing an aim and forming a hypothesis (eles-4205)

Interactivity
- Writing an aim and forming a hypothesis (int-8118)

1.7 SkillBuilder — Controlled, dependent and independent variables

eWorkbook
- SkillBuilder — Controlled, dependent and independent variables (ewbk-5297)

Video eLesson
- Controlled, dependent and independent variables (eles-4206)

Interactivity
- Controlled, dependent and independent variables (int-8119)

1.8 SkillBuilder — Measuring and reading scales

eWorkbook
- Skillbuilder — Measuring and reading scales (ewbk-5299)

Video eLesson
- Measuring and reading scales (eles-4207)

Interactivity
- Reading scales (int-0201)

1.9 SkillBuilder — Drawing a line graph

eWorkbook
- SkillBuilder — Drawing a line graph (ewbk-5301)

Video eLesson
- Drawing a line graph (eles-4208)

Interactivity
- Drawing a line graph (int-8120)

1.10 SkillBuilder — Creating a simple column or bar graph

eWorkbook
- SkillBuilder — Creating a simple column or bar graph (ewbk-5303)

Video eLesson
- Creating a simple column or bar graph (eles-4209)

Interactivity
- Creating a simple column or bar graph (int-8121)

1.12 Using spreadsheets

eWorkbooks
- Spreadsheeting and graphing (ewbk-5305)
- Calculating using a spreadsheet (ewbk-5307)

1.15 Review

eWorkbooks
- Topic review Level 1 (ewbk-5309)
- Topic review Level 2 (ewbk-5311)
- Topic review Level 3 (ewbk-5313)
- Study checklist (ewbk-5315)
- Literacy builder (ewbk-5316)
- Crossword (ewbk-5318)
- Word search (ewbk-5320)
- Reflection (ewbk-3038)

Digital document
- Key terms glossary (doc-35019)

To access these online resources, log on to **www.jacplus.com.au**.

2 Control and coordination

LEARNING SEQUENCE

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2.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

2.1.1 Introduction

You are a multicellular organism made up of a number of body systems that work together to keep you alive. Your body systems are made up of organs, which are made up of tissues, which are made up of particular types of cells. Your cells communicate with each other using electrical impulses in nerves and chemicals such as neurotransmitters and hormones. The coordination of this communication is essential so that the requirements of your cells are met and a stable internal environment is maintained.

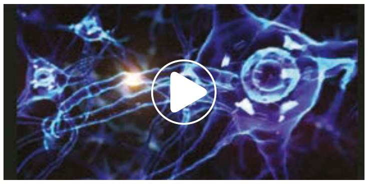
FIGURE 2.1 A scanning electron micrograph image of a human tongue

The image on the opening page of this topic shows a coloured light micrograph through a highly folded part of the brain called the cerebellum. The outer layer is the grey matter composed of the molecular layer (red) and the granular layer (bright green). The dark green is the white matter. Your cerebellum is only a small part of your brain but contains over half of your brains nerve cells, and it is involved in functions such as memory and language development. Figure 2.1 shows a scanning electron micrograph of the tongue surface of the papillae that give the tongue its texture. The papillae also contain the tastebuds, and are part of the sensory system that sends information to the brain.

on Resources

Video eLesson Neurons in the brain (eles-2631)

Watch this short animation demonstrating the interconnectedness between the neurons in the brain.



2.1.2 Think about control and coordination

1. How fast can a body react to threatening situations?
2. Can your reactions be consciously controlled in all situations?
3. Which body systems are used for a fight-or-flight response?
4. Which hormone causes male sex organs to grow?
5. What's the link between hormones and the menstrual cycle?
6. Which neurotransmitter acts like the brakes on your emotions?

2.1.3 Science inquiry

Speedy reactions?

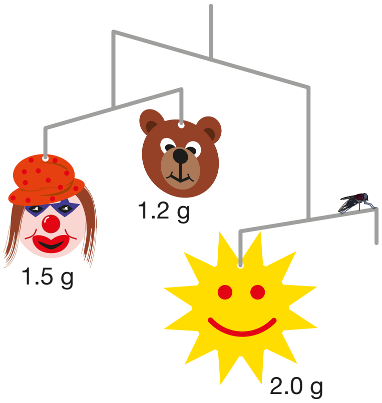
When you first see any danger, you detect it using receptors in your eyes. This message is then sent to your nervous system, which will tell your body what to do. Figure 2.2 shows potential dangers. In these situations your endocrine system may also react by producing hormones such as adrenaline to trigger your body to 'get up and go'. Hopefully this all happens fast enough to avoid anyone getting hurt! The time it takes to respond to a detected event (a stimulus) is known as the response time.

FIGURE 2.2 Dangers in everyday life are often detected using receptors in your eyes.

Answer the following questions, considering reaction time and different responses.

1. Read each of the following scenarios and responses and then order them from fastest to slowest response time.
   - **a.** *Scenario:* A mobile has lost a piece and is hanging crooked. When a fly lands on the mobile, it becomes balanced again. Given the masses in figure 2.3, what is the mass of the fly?
     Response: Solving the puzzle
   - **b.** *Scenario:* Ouch! You step on a sharp object.
     Response: You lift your foot quickly.
   - **c.** *Scenario:* You have been in three classes before lunch. You had very little breakfast and you feel that you have no energy. Your friend Janine, who knows everything, tells you that you have low blood sugar and must eat your lunch so that your blood sugar level can get back to normal. The bell rings, and you rush to the canteen to get lunch.
     Response: Getting your blood sugar back to normal
2. Consider the different ways you respond to your environment. Suggest reasons for the different types of responses and how your body processes the information to bring about the response.
3. Propose another scenario and predict what your body's response would be. Suggest why and how it would respond in this way.

FIGURE 2.3 What would be the response time to solve this puzzle?



4. Find out how seeing danger quickly approaching can result in a change of behaviour (such as running faster, stopping or screaming). Outline the involvement of both nerves and hormones.
5. An investigation is being conducted to determine reaction time to press a button when it glows red.
   - **a.** Write a suitable aim for this investigation.
   - **b.** Suggest a question or hypothesis for the scenario that you could investigate.
   - **c.** Describe one piece of qualitative data and one piece of quantitative data that may be collected.
   - **d.** What dependent and independent variables could there be?
   - **e.** Explain two factors that may lead to differences in results between different students.
   - **f.** Write a clear methodology for this investigation, with an explanation of how you collect results and how you will control variables.

Resources

eWorkbooks	Topic 2 eWorkbook (ewbk-5090) Student learning matrix (ewbk-5092) Starter activity (ewbk-5093)
Practical investigation eLogbook	Topic 2 Practical investigation eLogbook (elog-0625)
Weblink	Reaction time test
learnon	Access and answer an online Pre-test and receive **immediate corrective feedback** and **fully worked solutions** for all questions.

2.2 Coordination and control

LEARNING INTENTION

At the end of this subtopic you will be able to explain the main differences between the nervous and endocrine system and how they play an important role in multicellular organisms.

2.2.1 Working together

You are a **multicellular organism** made up of many cells that need to be able to communicate with each other. They need to be able to let other cells know when they need help and support, when they need more of something or when they need to get rid of something.

Your cells can be organised to form tissues. These tissues make up organs, and the organs make up systems, which perform particular jobs to keep you alive.

The cells of multicellular organisms cannot survive independently of each other. They depend on each other and work together. Working together requires organisation, coordination and control.

FIGURE 2.4 Multicellular organisms show a pattern of organisation in which there is an order of complexity.

Multicellular organisms $\xrightarrow{\text{contain}}$ Systems $\xrightarrow{\text{contain}}$ Organs $\xrightarrow{\text{contain}}$ Tissues $\xrightarrow{\text{contain}}$ Cells

While one of your cells may be a part of one of the systems in your body, it may also need to communicate and interact with *other* systems to stay alive.

For example:
- Your digestive system breaks down nutrients into a form that can be used by your cells.
- Your circulatory system delivers the useful products of digestion to your cells.
- Your respiratory system ensures oxygen is supplied to your cells and that carbon dioxide is removed away from them.
- Your excretory system removes wastes that may otherwise be toxic to you cells.

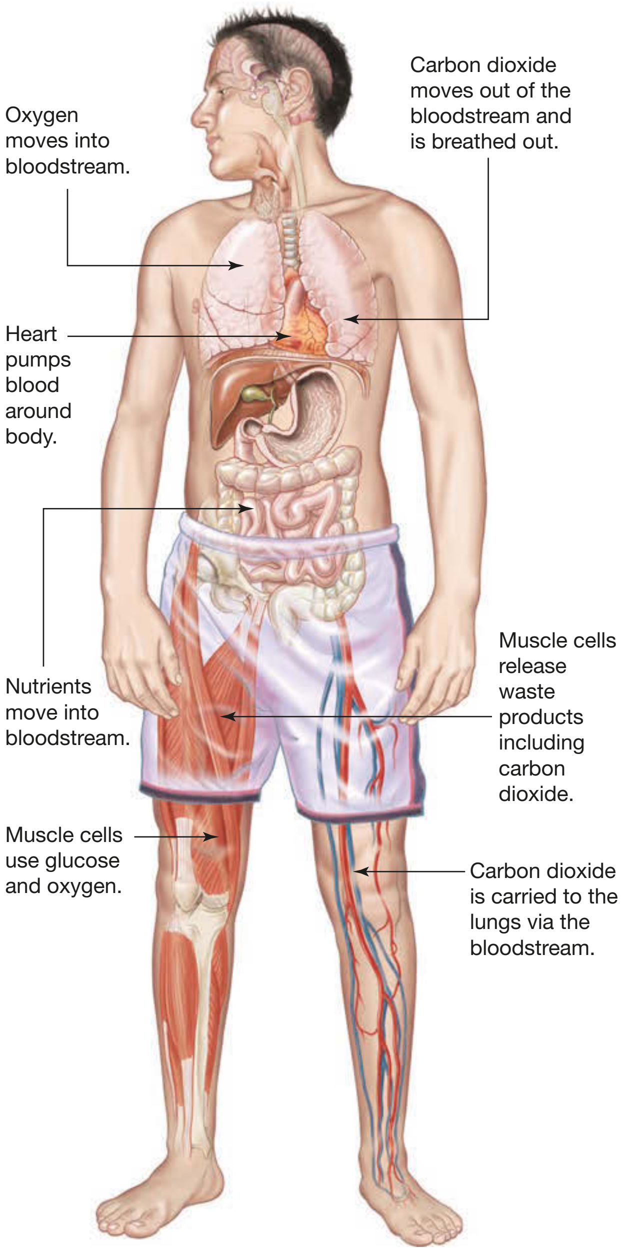
All of your systems need to work together so that a comfortable stable environment for your cells is maintained. The nervous system (including nerves and **neurotransmitters**) and the endocrine system (including glands and **hormones**) are vital in helping your systems work together.

multicellular organism a living thing that is composed of many cells

neurotransmitters signalling molecules released from the axon terminals into the synapse between nerve cells (neurons)

hormone a signalling molecule that is produced in specialised cells and travels in blood to act on target cells to cause a specific response

FIGURE 2.5 All body systems work together.



2.2.2 Stimulus–response model

Homeostasis

The internal environment in which your cells live needs to be kept constant. Temperature, pH and concentrations of ions, glucose, water and carbon dioxide need to be within a particular range. Maintenance of this constant internal environment is called **homeostasis**.

To be able to achieve homeostasis, any changes or variations (stimuli) in the internal environment need to be detected (by receptors). If a response is required, this needs to be communicated to **effectors** to bring about some type of change or correction so the conditions can be brought back to normal. This is described as a **stimulus–response model**.

homeostasis the maintenance by an organism of a constant internal environment (for example, blood glucose level, pH, body temperature)

effectors organs that respond to a stimuli to initiate a response

stimulus–response model a system in which a change (stimulus) is detected by receptors leading to a response, which acts to alter and return the variance to normal

FIGURE 2.6 The stimulus–response model

Stimulus → Receptor → Control centre → Effector → Response

Stimuli

There are various stimuli that your body needs to detect and, if necessary, respond to. Some of these stimuli may be outside of your body, such as environmental temperature or potentially dangerous (for example, hot or sharp) objects. Other stimuli may be inside your body, such as changes in body temperature and blood sugar, pH or water levels.

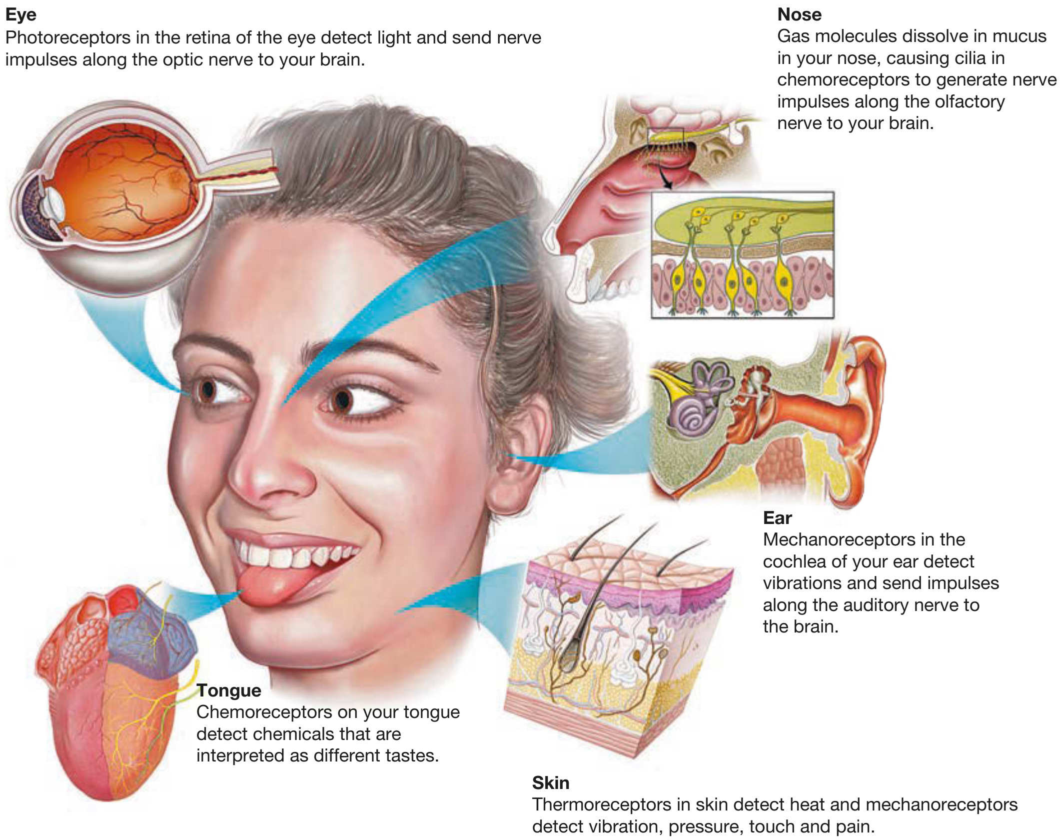
Receptors

Receptors identify changes inside and outside your body. These special types of nerve cells may be located in sense organs such as your eyes, ears, nose, tongue and skin (figure 2.7). Different types of receptors respond to particular stimuli (table 2.1). These will be further investigated in subtopic 2.4.

TABLE 2.1 Example of some different types of receptors

Type of receptor	Which stimuli does it respond to?	Main location in your body
Photoreceptor	Light	Eye
Mechanoreceptor	Pressure, movement and sound	Skin, hair and skin cells
Chemoreceptor	Chemicals	Tongue, nose
Thermoreceptor	Temperature	Skin

FIGURE 2.7 Examples of the receptors in the human body



Control centre

Once a stimulus has been detected by a receptor, a message in the form of a nerve impulse travels to the central nervous system (brain and spinal cord). It is here that the message is processed to determine which response will be appropriate. A message is then sent to the appropriate effector.

Effectors

Effectors such as muscles or glands receive the message from the central nervous system to respond in a particular way. Their response depends on the original stimulus. For example, if your hand is too close to a candle flame, then muscles in your arm may respond to move your hand away from it. If your body temperature increases too much, your sweat glands produce sweat to help cool you down (some other examples of this can be seen in figure 2.10, which summarises thermoregulation).

2.2.3 Giving feedback?

Stimulus–response models can also involve negative or positive feedback. Most biological feedback systems involve negative feedback.

Negative feedback

Negative feedback occurs when the response is in an opposite direction to the stimulus. It is a homeostatic mechanism that allows for the maintenance of variables within a set range. For example, if levels of a particular chemical in the blood were too high, then the response would be to lower them. Likewise, if the levels were too low, then they would be increased. The response is ’fed back’ into the system, allowing for further adjustments to be made if required.

The regulation of glucose levels in your blood involves negative feedback (figure 2.8). If an increase in blood glucose levels has been detected by receptors, the **pancreas** responds by secreting **insulin**, which may trigger an increased uptake of glucose by liver and muscle cells and the conversion of glucose into **glycogen** for storage. This lowers the blood glucose levels.

negative feedback a homeostatic mechanism that returns a stimulus back within its normal range

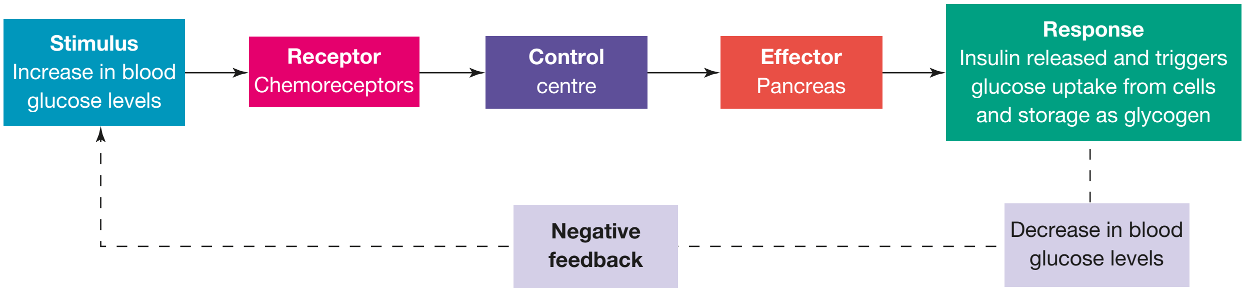
pancreas a large gland in the body that produces and secretes the hormone insulin

insulin hormone that reduces blood glucose levels

glycogen the main storage carbohydrate in animals, converted from glucose by the liver and stored in the liver and muscle tissue

positive feedback a homeostatic mechanism that enhances the original stimulus

FIGURE 2.8 The negative feedback loop involved when high blood glucose is detected.



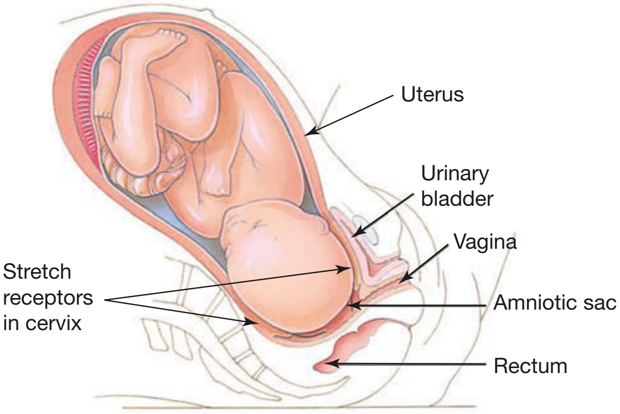
Positive feedback

Positive feedback results in the response going in the same direction as the change in stimulus. This causes an amplification of the response, moving it further away from the normal range. Examples of positive feedback include:

- when a mother is breastfeeding her baby:
  - Mechanoreceptors in her nipple detect the baby sucking.
  - The message is transferred to her central nervous system (in this case, her spinal cord) which then sends a message to muscles lining the milk glands to respond by releasing milk.

- The response continues until the baby stops sucking and the stimulus is removed.
- the increase in contractions during childbirth.
  - As the baby moves into the cervix (the area that connects the uterus to the vagina, as seen in figure 2.9), it causes stretching of receptors.
  - This results in the release of a hormone called **oxytocin**. Oxytocin causes the uterus to contract.
  - As the baby is pushed further into the cervix, the stretch receptors are further stretched, resulting in more oxytocin release and stronger contractions.
  - Once the baby is born, the stimulus disappears, so oxytocin levels drop, as do the contractions.

FIGURE 2.9 The process of childbirth involves a positive feedback loop.



2.2.4 How messages are sent in the body

To work together effectively, these systems require coordination. The two systems with this responsibility are the **nervous system** and the **endocrine system**. While both of these systems require signalling molecules to communicate messages throughout the body, they have different ways of going about it. The nervous system and endocrine system will be explored further in subtopics 2.3 and 2.6. The nervous system uses a combination of electrical and chemical signals. The endocrine system uses hormones.

TABLE 2.2 Comparison of messages sent through the endocrine and nervous systems

Feature	Endocrine system	Nervous system
Speed of message	Slow	Fast
Speed of response	Usually slow	Immediate
Duration of response	Long lasting	Short
Spread of response	Usually slow	Very localised
How message travels through body	In circulatory system — in bloodstream	In nervous system — along nerves and across synapses
Types of message	Hormones (chemicals)	Electrical impulse and neurotransmitters (chemicals)

2.2.5 Working together

An example of the nervous and endocrine systems working together is in the control of body temperature, referred to as **thermoregulation**. Evidence suggests that a part of your brain called the **hypothalamus** contains a region that acts as your body's **thermostat**. It contains thermoreceptors that detect the temperature of blood that flows through it.

If your body temperature increases or decreases from within a particular range, messages from thermoreceptors in your skin or hypothalamus trigger your hypothalamus to send messages to appropriate effectors. The effectors (such as those shown in figure 2.10) then bring about a response that may either increase or decrease body temperature. The nervous system and the endocrine system (through hormones such as adrenaline and thyroxine) are both vital in this response.

oxytocin a hormone that induces labour and milk release from mammary glands in females

nervous system the body system in which messages are sent as electrical impulses (along neurons) and chemical signals (neurotransmitters across synapses)

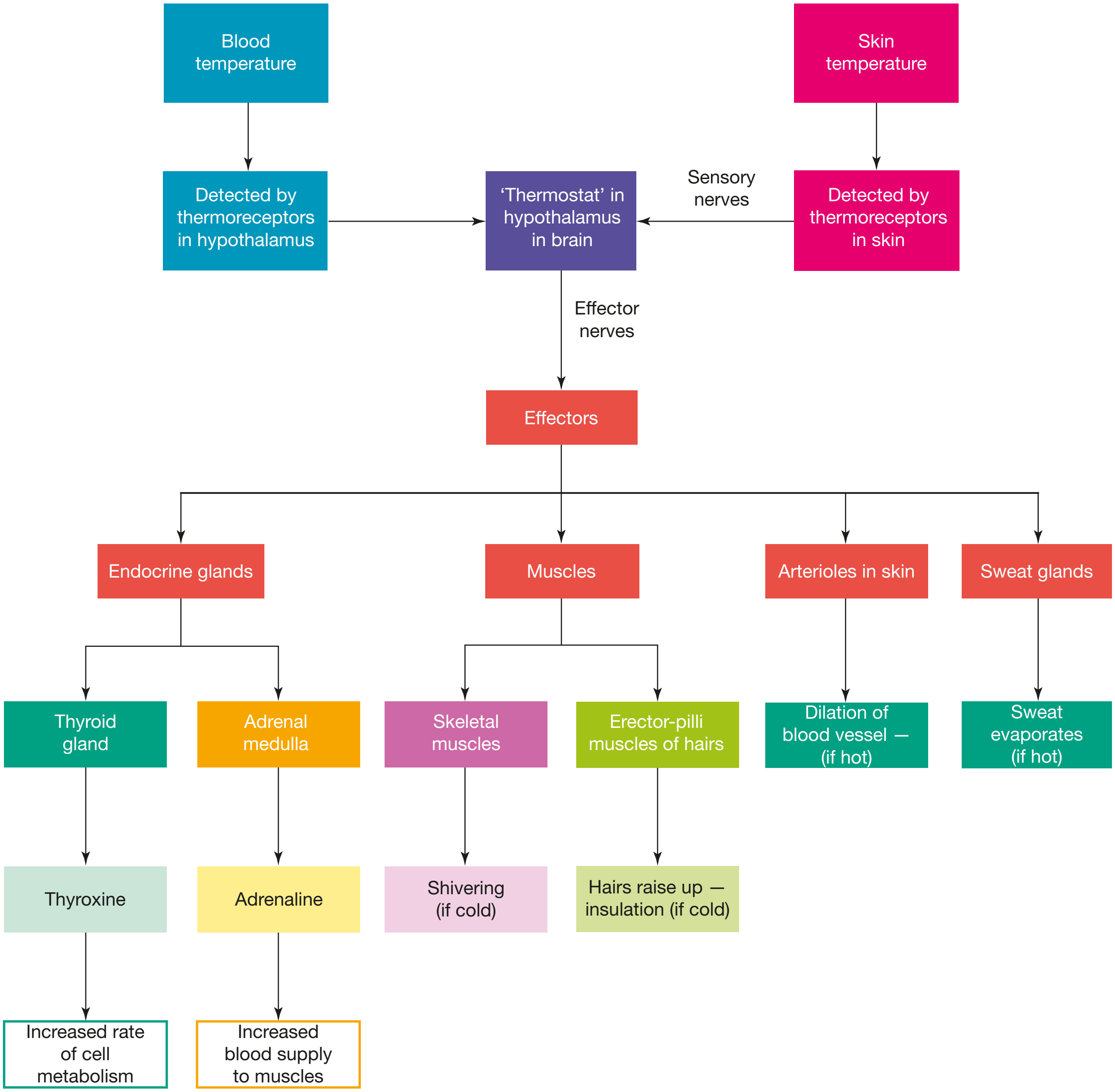
endocrine system the body system composed of different glands that secrete signalling molecules (hormones) that travel in the blood for internal communication and regulation and to maintain homeostasis

thermoregulation the control of body temperature

hypothalamus a part of the forebrain that monitors internal systems and coordinates the nervous and endocrine systems to maintain homeostasis

thermostat a device that establishes and maintains a desired temperature automatically

FIGURE 2.10 Temperature regulation is an example in which the nervous system and the endocrine system work together to maintain your body temperature within a range that is healthy for your cells.



on Resources

eWorkbook The stimulus–response model (ewbk-5095)

assess on Additional automatically marked question sets

2.2 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Match each of the following to its definition.

Term	Definition
a. Cells	**A.** different organs working together to perform a specialised function to keep an organism alive
b. Organ	**B.** a collection of similar cells that perform a particular function
c. System	**C.** different types of tissues grouped together to perform a particular function
d. Tissue	**D.** the smallest structural unit of living organisms

2. **MC** These detect or identify changes or variations on the inside or outside of your body.
   A. Effectors **B.** Receptors **C.** Response **D.** Stimuli
3. **MC** These bring about a response to changes or variations in the internal environment of your body.
   A. Effectors **B.** Receptors **C.** Response **D.** Stimuli
4. Identify the type of receptor that would respond to the following stimuli:
   a. light **b.** sound **c.** chemicals **d.** temperature.
5. Define each of the following terms:
   a. Stimulus–response model **b.** Control centre
   c. Effector **d.** Receptor

Apply and analyse

6. Identify each of the following as positive or negative feedback:
   a. Blood glucose levels increase and insulin returns this back to normal levels
   b. During a fever, the body temperature continues to increase away from the set body temperature
   c. When your body temperature decreases, thyroxine acts to increase your metabolism and increase your body temperature
   d. During childbirth, the release of oxytocin causes the cervix to dilate more and more.
7. Fill in the blanks using the following terms: effectors, receptors, response, stimuli.
   The stimulus–response model describes how __________, such as changes in the internal environment of your body, are detected by __________, which may communicate the message to __________ to bring about some kind of __________ so that conditions are brought back to normal.
8. Give an example of a negative feedback mechanism in the human body.
9. Distinguish between:
   a. receptors and effectors
   b. negative and positive feedback
   c. the endocrine system and the nervous system.

Evaluate and create

10. Construct a flow chart to show the relationship between the following:
    a. cells, organs, multicellular organisms, tissues
    b. effector, response, control centre, stimulus, receptor.

11. SIS Research the regulation and stimulus response model when blood glucose levels are too high.
   a. Create a flow chart showing how the nervous and endocrine system work to return blood glucose to normal.
   b. Describe why individuals with Type I diabetes cannot properly regulate blood glucose.
   c. Suggest some treatment options for individuals with Type I diabetes.

Fully worked solutions and sample responses are available in your digital formats.

2.3 The nervous system — fast control

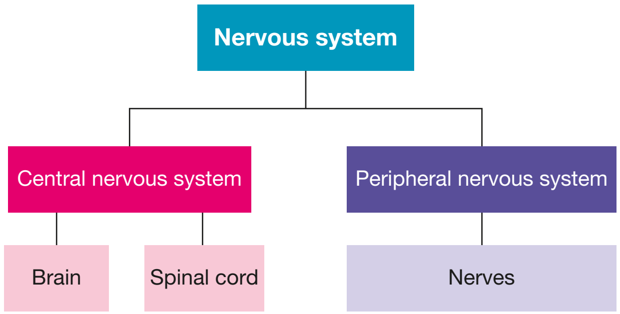
LEARNING INTENTION

At the end of this subtopic you will be able to explain the complexities of the nervous system and be able to describe how messages are transmitted from a stimulus to generate a response.

2.3.1 Components of the nervous system

Your nervous system is composed of:
- **central nervous system** (CNS) — contains brain and spinal cords
- **peripheral nervous system** (PNS) — contains the nerves that connect the central nervous system to the rest of the body.

FIGURE 2.11 The components of the nervous system



Messages are sent by:
- **sensory neurons** — take messages to the central nervous system
- **motor neurons** — take messages away from the central nervous system.

The nervous system sends the message as an electrical impulse along a neuron and then as a chemical message (neurotransmitters) across the gaps (synapses) between them. We will discuss this in detail later in this topic.

central nervous system the part of the nervous system composed of the brain and spinal cord

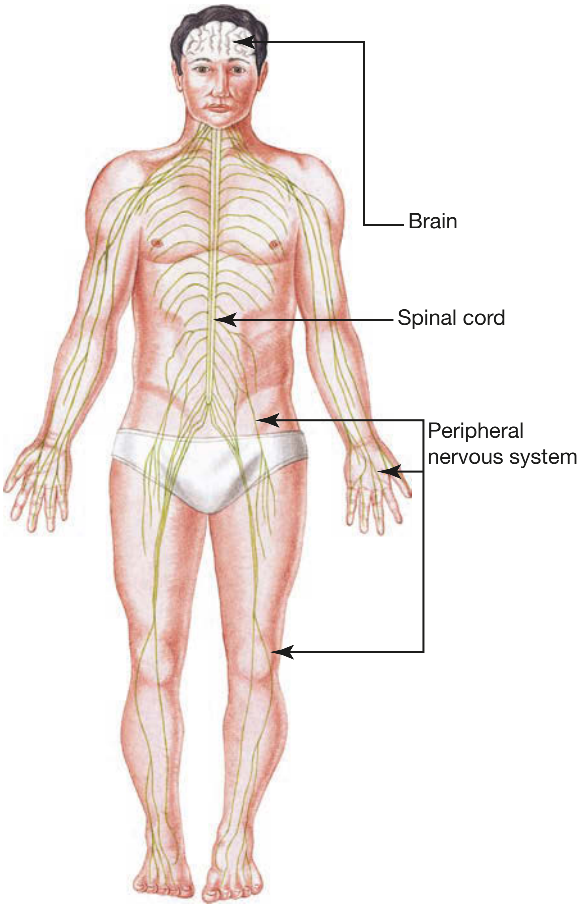
peripheral nervous system the part of the nervous system containing nerves that connect to the central nervous system

sensory neuron a nerve cell in the sensory organs that conducts a nerve impulse from receptors to the central nervous system

motor neuron a nerve cell that conducts a nerve impulse from the central nervous system to the effector, such as a muscle or gland so that it may respond to a stimulus

eles-2632

FIGURE 2.12 The human nervous system



2.3.2 Neurons

Whether you are catching a ball, slicing carrots, breathing or stopping a fall, you need to be in control. You need to be able to detect and respond in ways that ensure your survival. This requires control and coordination. Your nervous system assists you in keeping in control, and coordinating other body systems, so that they work together and function effectively.

Your nervous system is composed of the central nervous system (brain and spinal cord) and the peripheral nervous system (the nerves that connect the central nervous system to the rest of the body). These systems are made up of nerve cells called **neurons**. The axons of neurons are grouped together to form **nerves**.

Structure of a neuron

Neurons contain a **nucleus** and other cell **organelles**. They also contain a **cytosol** and cell membrane like other cells. However, the various types of neurons are all quite different. These differences mean that each particular neuron type is suited to its specific communication role in the nervous system. These differences are shown in table 2.3.

neuron another name for nerve cell, a specialised cell for transmitting a nerve impulse

nerve a bundle of neurons

nucleus roundish structure inside a cell that acts as the control centre for the cell

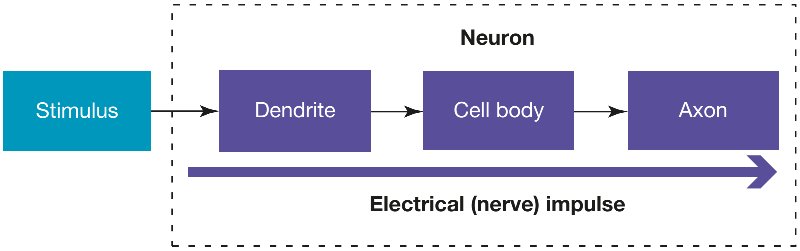
organelle small structure in a cell with a special function

cytosol the fluid found inside cells

Neurons are made up of three main parts:

- a **cell body** — contains the nucleus of a neuron
- **dendrites** — highly sensitive branching extensions on the cell membrane of the cell body; these dendrites possess numerous receptors that can receive messages from the other cells
- **axon** — a long structure of the neuron that carries the electrical message from the dendrite and the cell body. This structure is often covered with a white insulating substance called **myelin**, which helps speed up the conduction of the message through the neuron.

FIGURE 2.13 An electrical impulse moves in only one direction through a neuron.



The grey matter of the brain and spinal cord mainly consists of nerve cell bodies and dendrites. The white matter of the brain is linked to the process of **myelination**, where neurons are coated in a white material called myelin (figure 2.14). The myelin coat acts like the plastic material wrapped around electrical wires for insulation. While myelination of neurons insulates, it also increases the speed at which the nerve impulse can move through it and hence the speed at which the message is communicated. Images using **magnetic resonance imaging (MRI)** technology show that the amount of grey matter in the brain is reduced throughout childhood and adolescence and the amount of white matter increases.

cell body part of a neuron that contains the nucleus

dendrite structure that relays information towards the cell body of a neuron

axon long structure within a neuron through which the nervous impulse travels from the dendrite and the cell body

myelin a fatty, white substance that encases the axons of neurons

myelination the process of neurons becoming coated in a myelin sheath

magnetic resonance imaging (MRI) a medical imaging technique employing a powerful magnetic field and radio waves to produce a 3D image of a body

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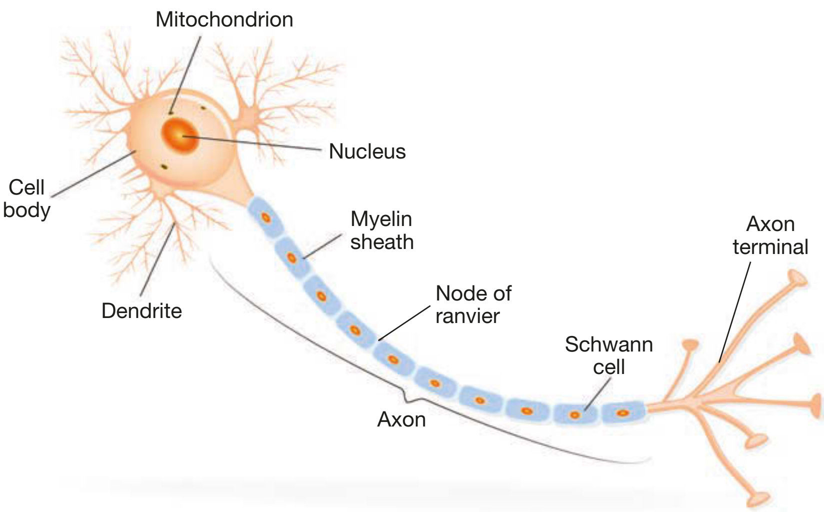
FIGURE 2.14 The components of a neuron



Types of neurons

There are three different types of neurons:

- sensory neurons, which carry the impulse generated by the stimulus to the central nervous system
- **interneurons**, which carry the impulse through the central nervous system
- motor neurons, which take the impulse to effectors such as muscles or glands.

interneuron a nerve cell that conducts a nerve impulse within the central nervous system, providing a link between sensory and motor neurons

FIGURE 2.15 Relationship between the different neurons in the nervous system

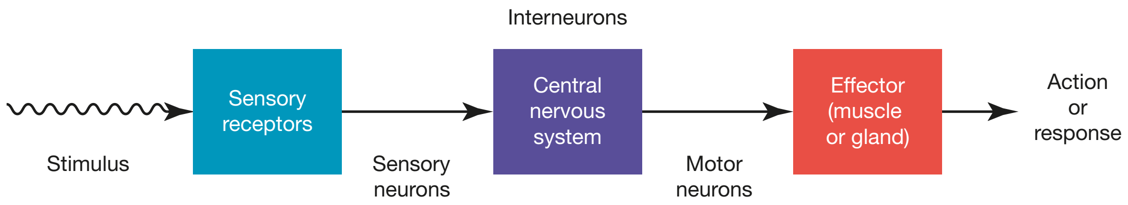
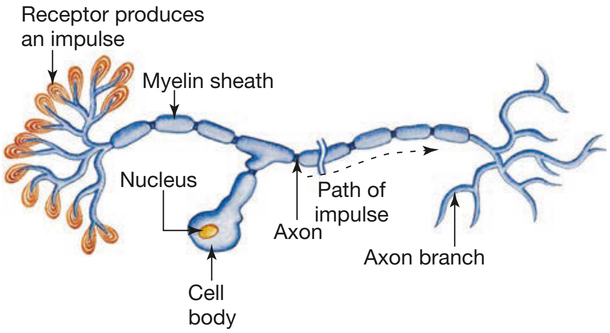
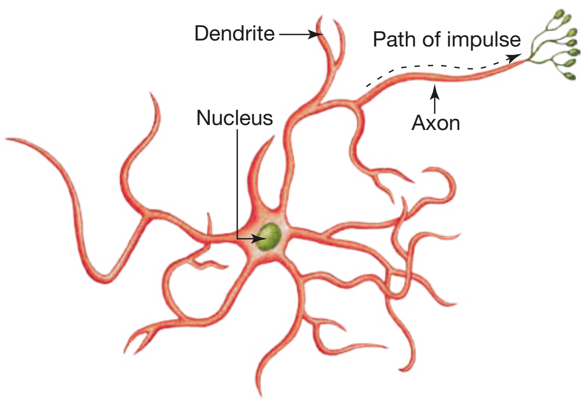


TABLE 2.3 The structure of different types of neurons

Type of neuron	Function	Structure
Sensory neurons	The sensory neurons in the sense organs detect changes in the environment. Messages about the changes are then relayed as impulses to an interneuron. Sensory neurons are part of the PNS.	
Interneurons	The interneurons carry impulses through the spinal cord and brain. So, they are part of the CNS. Interneurons are sometimes called connector neurons. Impulses are relayed from interneurons to motor neurons.	

(continued)

TABLE 2.3 The structure of different types of neurons *(continued)*

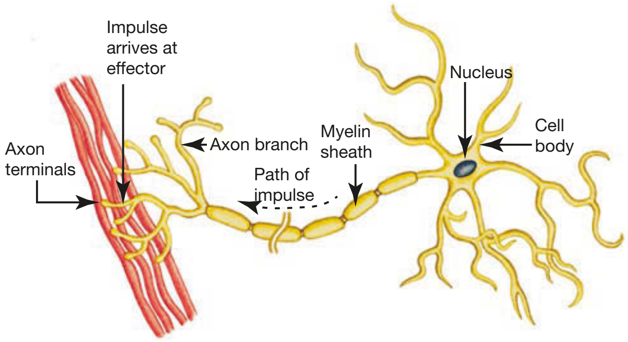
Type of neuron	Function	Structure
Motor neurons	The motor neurons receive impulses from interneurons and cause a response in an effector organ such as a muscle or a gland. Motor neurons are part of the PNS.	

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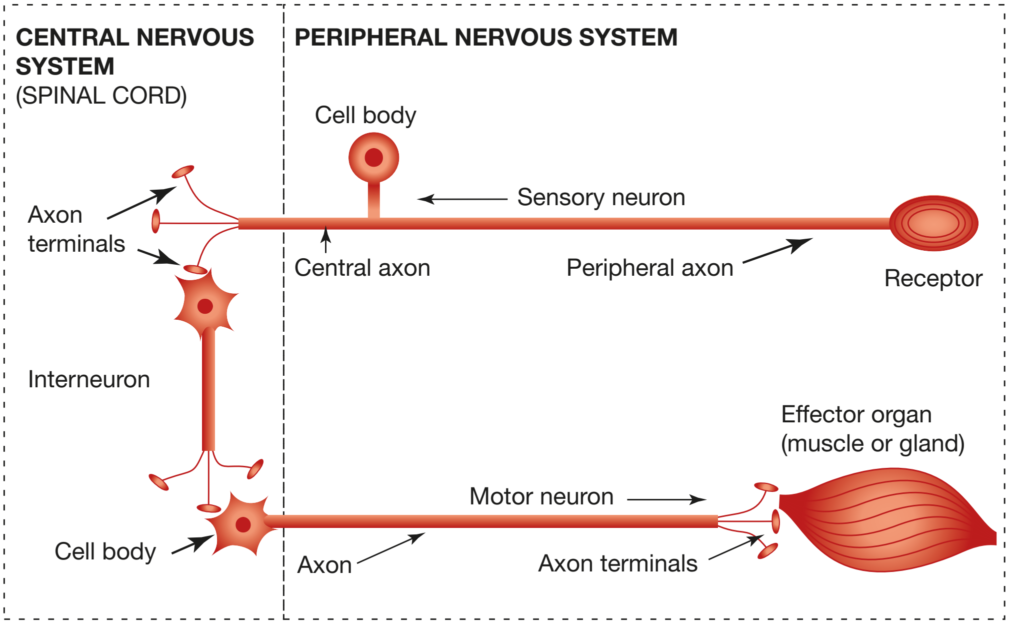
FIGURE 2.16 Relationship between the different kinds of neurons



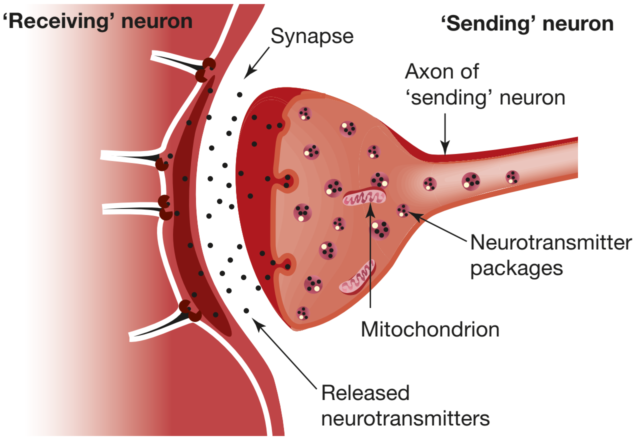
ACTIVITY: Neuron models

Make models of the different neuron types using balloons, string or cotton, straws and tape.

2.3.3 Synapses

The gap between neurons is called a **synapse**. The nerve impulse cannot jump across the synapse so when the nervous impulse has reached the axon terminal of a neuron, tiny **vesicles** containing chemicals called neurotransmitters are transported to the cell membrane of the neuron. These chemicals are then released into the synapse, as seen in figure 2.17.

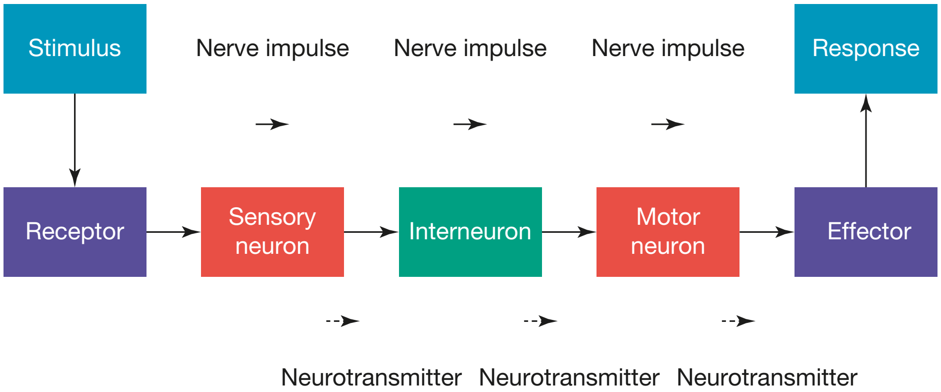
FIGURE 2.17 Neurotransmitters passing along the synapse to the next neuron



1. The neurotransmitters move across the synapse and bind to receptors on the membrane of the dendrites of the next neuron.
2. This may result in triggering the receiving neuron to convert the message into a nervous impulse and conduct it along its axon.
3. When it reaches the axon terminal, neurotransmitters are released into the synapse to be received by the dendrites of the next neuron.
4. This continues until the message reaches a motor neuron, which then communicates the message to an effector, such as a muscle or gland. The effector may then respond to the message; for example, a muscle cell may contract or a gland may secrete a chemical.

Your nervous system involves the use of both electrical signals (nerve impulses) and chemical signals (neurotransmitters) in order to detect a change in stimulus and initiate a response.

FIGURE 2.18 Your nervous system involves the use of both electrical signals (nerve impulses) and chemical signals (neurotransmitters).



on Resources

eWorkbook Labelling a synapse (ewbk-5099)

Video eLesson Brain cell synapse (eles-2634)

synapse the gap between adjoining neurons where neurotransmitters travel

vesicle a small fluid-filled, membrane-bound sac in a cell

2.3.4 Reflex actions

Sometimes, you need to consciously think about what your body does. However, at other times, actions happen without you having to think about them.

Have you ever had sand thrown in your eyes or touched something too hot? Or had a 'knee-jerk' reaction when a doctor sharply taps your knee? Sometimes you don't have time to think about how you will react to a situation. Some actions need to be carried out very quickly — it may be a matter of survival! These actions are examples of reflex actions.

You also react to many internal stimuli using reflex actions. Breathing, for example, is a response regulated by chemoreceptors detecting changes in carbon dioxide levels in your blood. It's very helpful that you don't have to remember to breathe — imagine what would happen if you forgot to!

FIGURE 2.19 You don't need to think what to do when you touch something hot.

Reflex actions may involve only a few neurons and require no conscious thought. Their pathway travels only to and from the spinal cord, and is called a **reflex arc**. An example of this process is outlined in figure 2.20.

1. A stimulus is encountered (in either the internal or external environment).
2. The stimulus is detected by a receptor.
3. The message is sent via the sensory neuron to the interneuron in the spinal cord.
4. Interneurons in the spine send the message to the motor neuron.
5. Motor neurons send the message to the effector to bring about a response.
6. The response occurs.

reflex arc a quick response to a stimulus that does not involve the brain (for example, knee jerk). The message travels from receptor to sensory neuron to interneuron in the spinal cord then directly via the motor neuron to the effector.

One important feature of the reflex arc is that a response occurs without the message needing to go to the brain.

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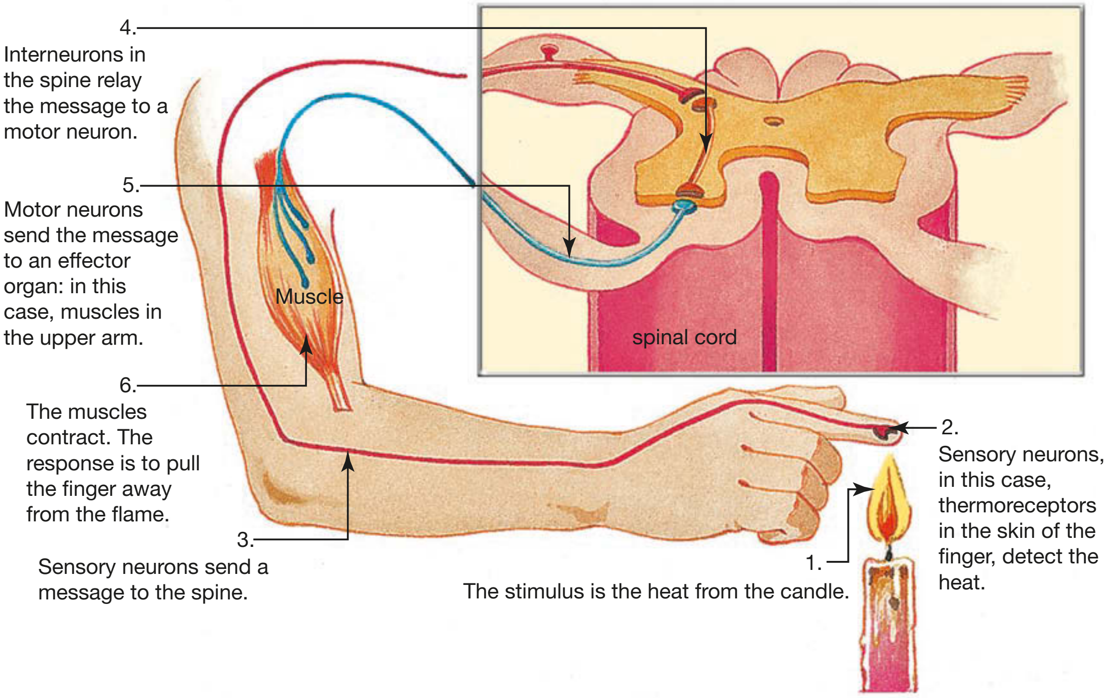
FIGURE 2.20 The reflex arc pathway does not go via the brain.



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INVESTIGATION 2.1

How good are your reflexes?

Aim

To investigate some automatic responses

Materials

- well-lit room
- chair
- stopwatch or clock with a second hand

Method

Work in pairs for both parts of this activity. Decide who will be the experimenter and who will be the subject. Then swap roles and repeat both parts.

Part A: Kept in the dark

1. If you are the experimenter, look closely at the eyes of your partner, noting the size of the pupils.
2. Ask your partner to close his or her eyes for 60 seconds.
3. At the end of this time, monitor your partner's eyes for any changes.

Part B: Knee jerk

4. Have your partner sit on a chair with one leg crossing over the other knee as shown.
5. Use the edge of your hand to gently strike the crossed leg of your partner just below the knee in the joint.
   You may need to repeat this a few times to get a response from your partner.

Results

Record your observations from Part A and Part B.

Discussion

Part A: Kept in the dark

1. What changes did you notice?
2. Identify the (a) stimulus and (b) response.
3. Why do you think this reflex action is important to our survival?
4. Can you control the size of your pupil?

Part B: Knee jerk

5. Identify the (a) stimulus, (b) response and (c) effector.
6. Did you get the response the first time? Why or why not?
7. Can you control a knee-jerk response?
8. Suggest possible improvements to this experiment and suggest further relevant investigations that could be carried out.

Conclusion

Summarise your overall findings and outline why the reactions seen in both parts of the experiment are examples of reflex actions.

2.3.5 Conscious response

More complex actions involve many interconnecting neurons and specialised parts of the brain. The messages pass into and along the spinal cord and the brain to be interpreted. When *thinking* takes place, we can make decisions about which responses are needed. Impulses are then sent along appropriate motor neurons to the effectors. This is called a *conscious response*.

Many learned actions can become automatic if the same pathways are used often enough. Skill development and control in playing musical instruments and sport, for example, depend on practice during which the same pathways are often used.

CASE STUDY: Pests and poisons

Have you ever been bitten or stung by an insect, animal or plant? Do you remember what the pain felt like? Why was it so painful? Blue-ringed octopuses, paralysis ticks, tiger snakes and other animals and plants produce cocktails of poisons that block the production and action of neurotransmitters at synapses. The poison from a red-back spider, for example, causes rapid release and depletion of neurotransmitters. Interfering with the neurotransmitters' job of carrying the message to the next neuron interferes with the transference of the message and can cause spasms and paralysis.

Many plants produce chemicals that sting by strongly stimulating the pain receptors in the skin. Messages are sent rapidly to the brain, which interprets them as pain. Other plants, including chrysanthemums, produce insecticides such as pyrethrums. These target the nervous system of insects, resulting in their death. The commercial production of such natural pesticides is a large industry and is regarded as environmentally friendly because natural pesticides replace the use of more harmful chemicals. Can you think of any other plants that can defend themselves like this?

FIGURE 2.21 Red-back spiders produce a toxin that impacts the release of neurotransmitters.

SCIENCE AS A HUMAN ENDEAVOUR: Chemical weapons

Chemicals similar to those found in poisonous plants and animals have been used as agents of human warfare. These chemicals specifically target the nervous system. Nerve gas, for example, contains a substance that prevents neurotransmitters functioning properly at the synapses. The neurotransmitters accumulate, causing the nervous system to go haywire. Such chaos can result in death.

The first nerve gas, tabun, was initially developed when German scientists were developing a better insecticide. This has led to more deadly agents such as sarin and VX. All nerve gases block the body's production of an enzyme called acetylcholinesterase. This enzyme regulates the nerves controlling the action of particular muscles. A deficiency of acetylcholinesterase leads to tightening of your diaphragm, convulsions and death.

FIGURE 2.22 Scientists and experts working with dangerous chemicals that target the nervous system must use protective suits.

DISCUSSION

Is the use of chemical warfare ever justifiable? Discuss this with your class, recording all the various opinions and views.

on Resources

eWorkbook The nervous system (ewbk-5103)

assess**on** Additional automatically marked question sets

2.3 Exercise

learn**on**

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

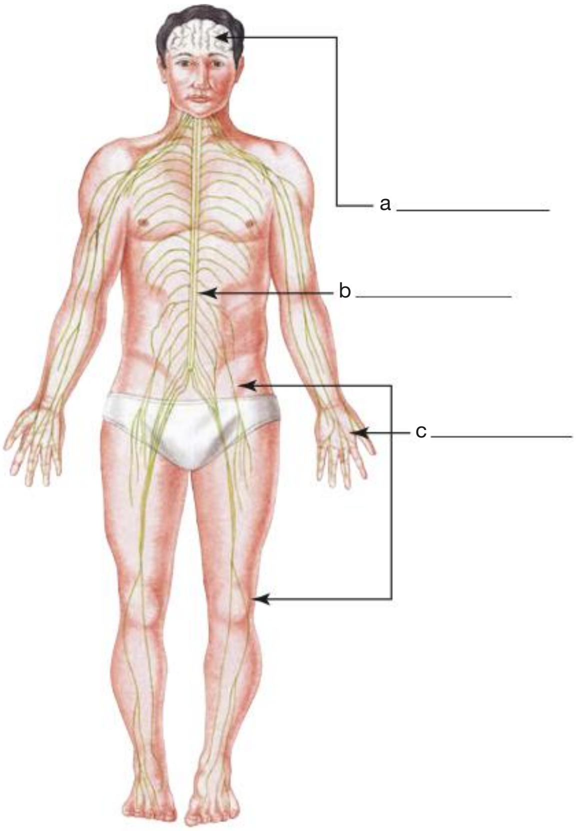
Remember and understand

1. Fill in the blanks using the following terms: brain, central, nerves, peripheral.

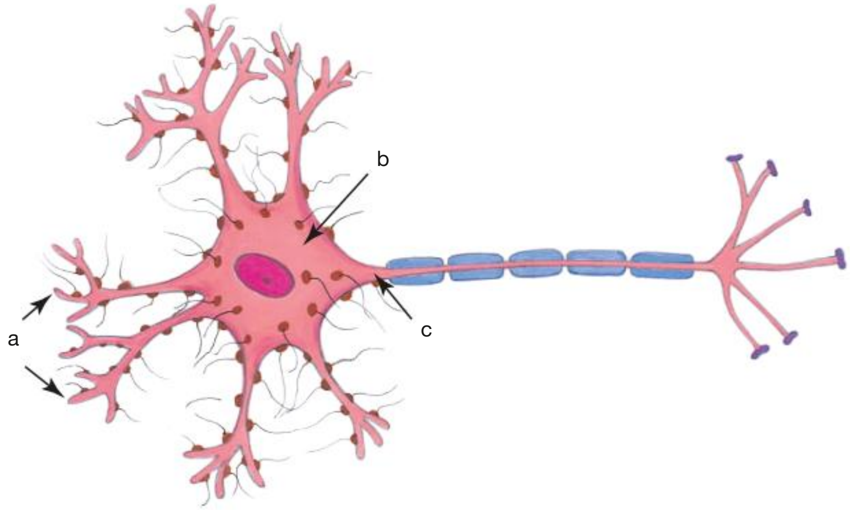
   The human nervous system is composed of the ____________ nervous system (____________ and spinal cord) and the ____________ nervous system (the ____________ that connect the central nervous system to the rest of the body).
2. Match the term with its description in the table provided.

Term	Description
a. Central nervous system	**A.** Gap between neurons
b. Motor neuron	**B.** Made up of neurons
c. Nerves	**C.** Nerves that connect the central nervous system to the rest of the body
d. Neuron	**D.** Takes messages to the central nervous system
e. Neurotransmitter	**E.** Made up of a cell body, dendrites and axon
f. Peripheral nervous system	**F.** Brain and spinal cord
g. Sensory neuron	**G.** Chemical messenger that carries messages from one neuron to another across a synapse
h. Synapse	**H.** Takes messages away from central nervous system

3. Identify the components of the nervous system and describe their function.



4. Label the cell body, dendrites and axon on the motor neuron and show the direction in which the impulse travels.



5. Distinguish between:
   a. a receptor and an effector
   b. a sensory neuron, an interneuron and a motor neuron
   c. a neuron and a nerve.
   d. a reflex action and conscious reaction.

Apply and analyse

6. Suggest how the structure of the different types of neurons suits them to their function.
7. Describe the advantage of the presence of myelin on the axon of a neuron.
8. With reference to chemical and electrical signalling in nerve cells, describe one way in which animals can cause paralysis.

9. a. Place a tick in the table provided for the responses that are reflex actions and that are conscious responses:

Action	Reflex action	Conscious response
Sneezing		
Blinking		
Scratching your head		
Knee-jerk reaction		
Clapping		
Breathing		

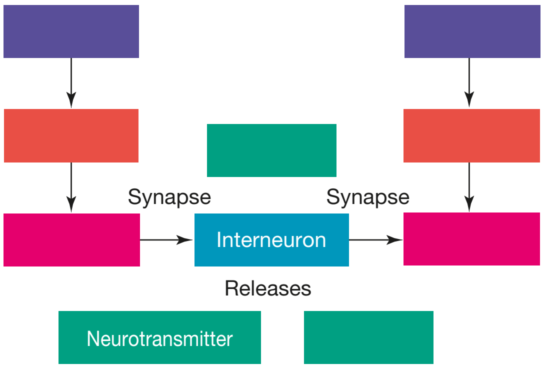
b. Explain how you decided if each action was a reflex or conscious reaction.

Evaluate and create

10. Organise the terms below into a Venn diagram of the nervous system and the endocrine system.

Central nervous system	Electrical impulse
Endocrine gland	Glucagon
Insulin	Homeostasis
Hormone	Motor neuron
Neurotransmitter	Pancreas
Peripheral nervous system	Sensory neuron
Stimulus–response model	Negative feedback

11. Suggest how you could link the nervous system terms in the flow chart provided.
- Electrical impulse
- Motor neuron
- Sensory neuron
- Response
- Receptor
- Neurotransmitter
- Stimulus
- Effectors



12. a. SIS Suggest a reason why the pupil of your eye increases in size in dim light.
b. Outline some triggers that may cause the size of your pupil to change in size.
13. How does blocking the production and action of neurotransmitters cause paralysis? Include a diagram to show this.
14. SIS Imagine that you are a scientist involved in researching the nervous system. Propose a relevant question or suggest a hypothesis for a scientific investigation and outline how you would design your investigation.
15. SIS There is a danger that chemical and biological weapons may one day be used in acts of terrorism.
a. Search the media for relevant examples of chemicals and their effects. Report on your findings of this.
b. What sorts of strategies do we have in Australia to cope with threats of chemical warfare?

Fully worked solutions and sample responses are available in your digital formats.

2.4 Getting the message

LEARNING INTENTION

At the end of this subtopic you will be able to describe the links and differences between the senses and different types of receptors in the human body.

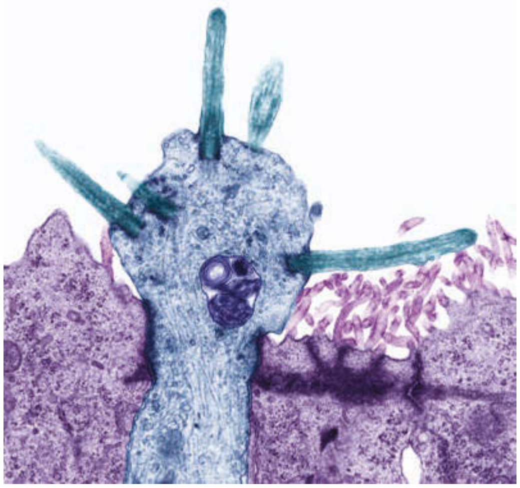
2.4.1 Your senses

Watch out! Your survival can depend on detecting changes in your environment.

Imagine not being about to see, hear, feel or sense the world outside your body. No sound, no colour, no taste or smell — just darkness and silence. Without senses, you might not even be able to sense that!

Sense organs are used to detect stimuli (such as light, sound, touch, taste and smell) in your environment. Examples of human sense organs are your eyes, ears, skin, tongue and nose. These sense organs contain special cells called receptors. These receptors are named according to the type of stimuli that they respond to (as shown in table 2.4). You have photoreceptors for vision, chemoreceptors for taste and smell and mechanoreceptors for pressure, touch, balance and hearing.

FIGURE 2.23 Transmission electron microscope (TEM) image of a chemoreceptor



Five receptors

1. **Thermoreceptors** enable you to detect variations in temperature and are located in your skin, body core and part of your brain, called the hypothalamus.
2. **Mechanoreceptors** are sensitive to touch, pressure, sound, motion and muscle movement and are located in your skin, skeletal muscles and inner ear.
3. **Chemoreceptors** are sensitive to particular chemicals and are located in your nose and tastebuds.
4. **Photoreceptors** are sensitive to light and are located only in your eyes.
5. **Pain receptors** enable you to respond to chemicals released by damaged cells. Detection of pain is important because it generally indicates danger, injury or disease. Although these receptors are located throughout your body, they are not found in your brain.

Each type of receptor is a different shape to respond to a different stimulus (table 2.4).

sense organ a specialised structure that detects stimuli (such as light, sound, touch, taste and smell) in your environment

thermoreceptors special cells located in your skin, part of your brain and body core that are sensitive to temperature

mechanoreceptors special cells within the skin, inner ear and skeletal muscles that are sensitive to touch, pressure and motion

chemoreceptors special cells within a sense organ that are sensitive to particular chemicals

photoreceptor a special cell located in your eye that is stimulated by light

pain receptors special cells located throughout the body (except the brain) that send nerve signals to the brain and spinal cord in the presence of damaged or potentially damaged cells

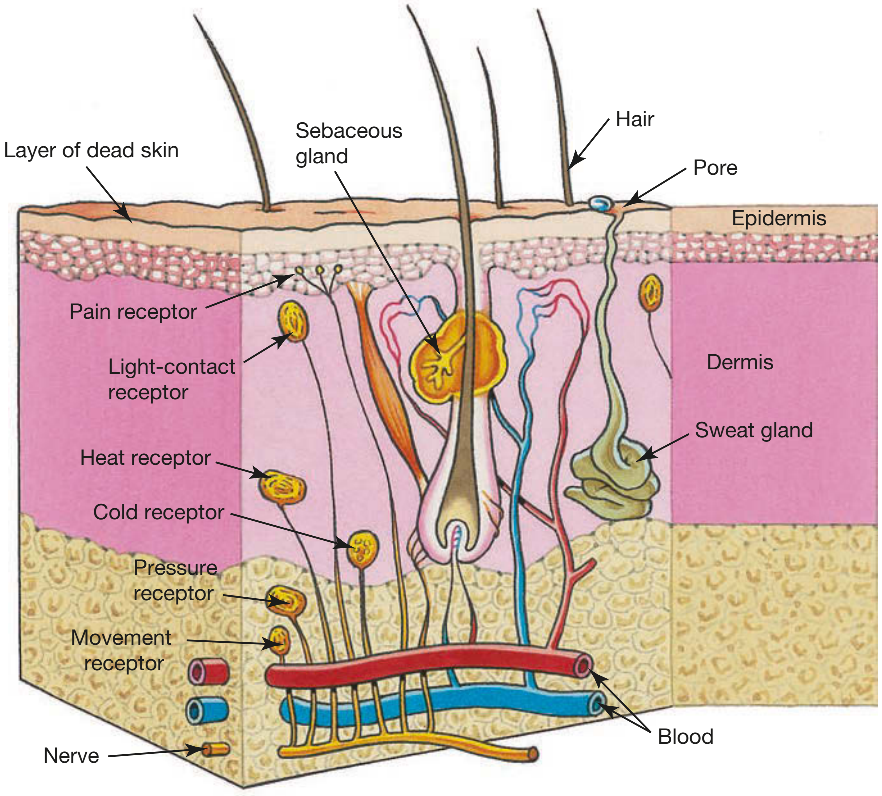
TABLE 2.4 Examples of different types of receptors

Sense	Sense organ	Stimulus	Receptor	Type of receptor
Sight	Eye	Light	Rods and cones in the retina	Photoreceptor
Hearing	Ear	Sound	Hairs in the cochlea	Mechanoreceptor
Touch	Skin	Heat, cold, pressure, movement	Separate receptors for each type of stimulus	Thermoreceptor Mechanoreceptor
Taste	Tongue	Chemical substances: sweet, salty, bitter and sour	Tastebuds	Chemoreceptors
Smell	Nose	Chemicals: odours	Olfactory nerves inside the nose	Chemoreceptors

2.4.2 Touch receptors

Your skin contains a variety of types of receptors (figure 2.24). Pain receptors and mechanoreceptors enable you to detect whether objects are sharp and potentially dangerous. There are also hot thermoreceptors that detect an increase in skin temperature above the normal body temperature (37.5 °C) and cold thermoreceptors that detect a decrease below 35.8 °C. These thermoreceptors can also protect you from burning or damaging your skin. The sensitivity of these receptors can depend on how close together they are and their location in your skin.

FIGURE 2.24 Your skin contains a variety of receptors that provide you with a sense of touch.



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INVESTIGATION 2.2

Touch receptors in your skin

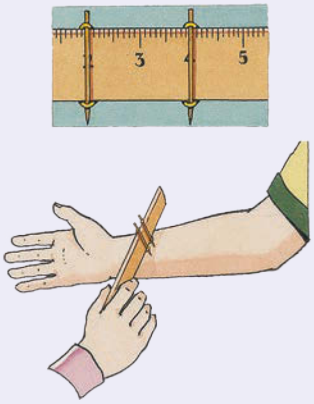
Aim

To detect where the skin is most sensitive to light contact

Materials

- 2 toothpicks
- ruler
- 2 rubber bands
- blindfold

Method



1. Use rubber bands to attach two toothpicks to a ruler so that they are 2 cm apart.
2. Predict in which areas of the body the skin will be most sensitive and least sensitive.
3. Blindfold your partner. Gently touch your partner's inside forearm with the points of the two toothpicks. Ask your partner whether two points were felt.
4. Move one toothpick towards the other in small steps until your partner is unable to feel both points. To make sure that there is no guesswork, use just one point from time to time.
5. Record the distance between the toothpicks when your partner can feel only one point when there are really two points in contact.
6. Repeat this procedure on the palm of one hand, a calf (back of lower leg), a finger and the back of the neck.
7. Swap roles with your partner and repeat the experiment.

Results

Record your observations in the table.

TABLE Observations for the distance between two points on different parts of the skin

Part of the skin	Distance (cm) between two points when only one point is felt	
	Your partner	You
Inside forearm		
Palm of hand		
Calf		
Finger		
Back of neck		

Discussion

1. Which touch receptors were being used in this experiment?
2. Construct a graph to represent your data and comment on observed patterns.
3. Which area of the skin was (a) most sensitive and (b) least sensitive?
4. Suggest why the skin is not equally sensitive all over the body.
5. Which parts of the skin are likely to have the most contact receptors?
6. Discuss how your predictions compared to your experimental results.
7. Suggest improvements to this investigation and further experiments to investigate contact receptors.

Conclusion

Summarise your overall findings.

2.4.3 Smell receptors

The sweet scent of a rose or the stink of garbage? Gaseous molecules from the air are breathed in through your nose. When dissolved in the mucus of your nasal cavity, the hair-like cilia of your nasal chemoreceptors are stimulated to send a message via your **olfactory nerve** to your brain to interpret it, giving you the sensation of smell (figure 2.25).

olfactory nerve nerve that sends signals to the brain from the chemoreceptors in the nose

FIGURE 2.25 A flow chart of how we process smell

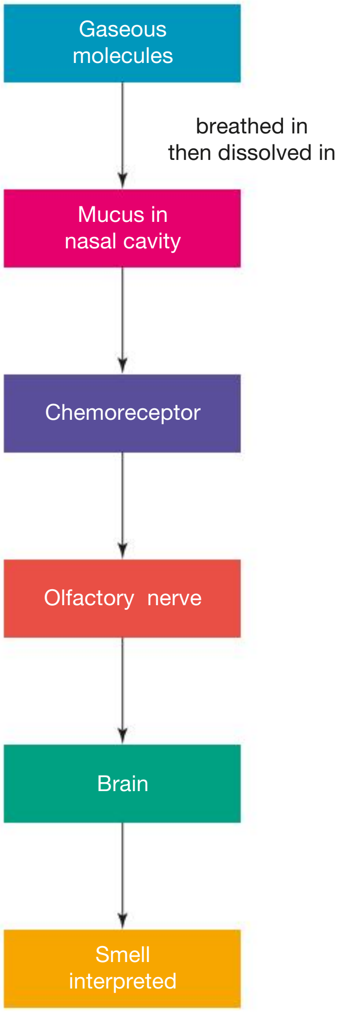
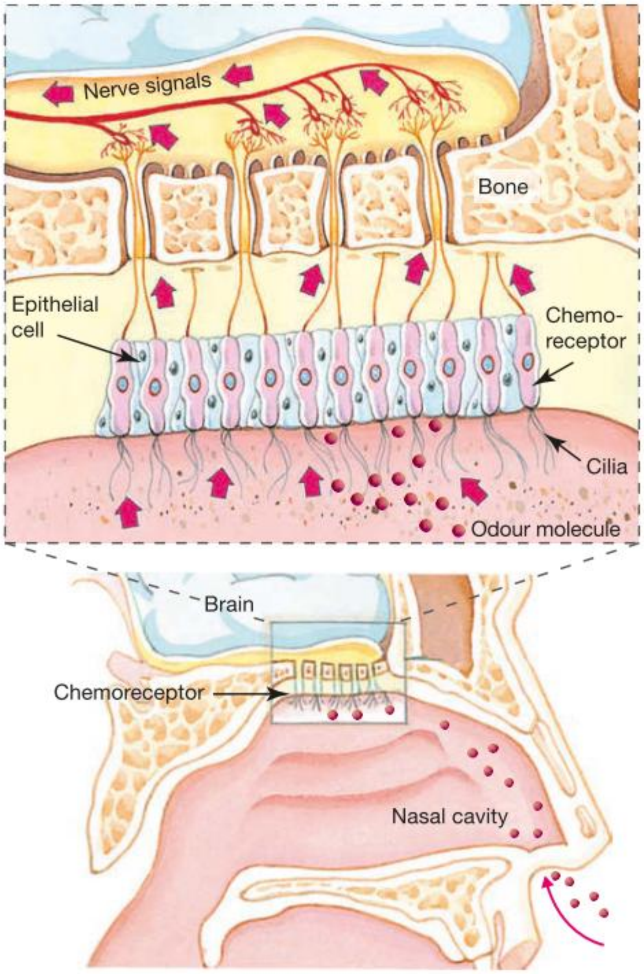


FIGURE 2.26 Chemoreceptors in your nose enable you to have a sense of smell.



2.4.4 Sight receptors

Your eyes, like your other sense organs, are made up of many different parts, each with its own special job to do. Look into a mirror (or into the eyes of the person next to you) and you will see:

- the **iris** is the coloured part of your eye, which is a ring of muscle
- the **pupil** is the dark spot in the centre of your eye. Your pupil is simply a hole in the iris

iris coloured part of the eye that opens and closes the pupil to control the amount of light that enters the eye

pupil a hole through which light enters the eye

As your iris is a ring of muscle, when it relaxes the pupil appears bigger, letting more light into the eye; and when it contracts, the pupil looks smaller, letting less light into the eye. In a dark room, your pupil is large so that as much light as possible can enter your eye. If you were to move outside into bright light, your pupil would become smaller. This reflex action helps to protect your eyes from being damaged from too much light.

cornea the curved, clear outer covering of your eye

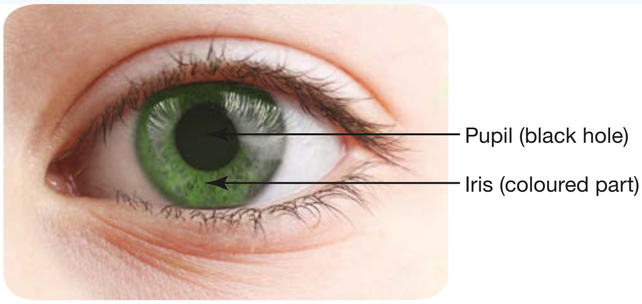
lens a transparent curved object that bends light towards or away from a point called the focus

retina curved surface at the back of the eye

cones photoreceptors located in the retina that respond to red, green or blue light

rods photoreceptors located in the retina that respond to low levels of light and allow you to see in black and white in dim light

FIGURE 2.27 The iris and the pupil in the eye



Structure of the eye

The **cornea** is the clear outer 'skin' of your eye. It is curved so that the light approaching your eye is bent towards the pupil. The clear, jelly-like **lens** bends or focuses light onto a thin sheet of tissue that lines the inside of the back of your eye called the **retina**. The lens is connected to muscles, which can make it thick or thin. This allows your retina to receive a sharp image of distant or nearby objects. Your retina contains photoreceptor cells called **cones** and **rods**. The rod cells detect light intensity and the cone cells respond specifically to colour (figure 2.28).

FIGURE 2.28 A scanning electron micrograph of the rod (purple) and cone (blue) cells in the eye.

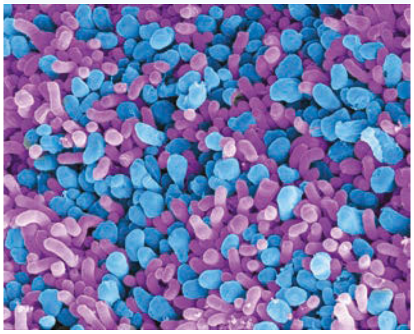


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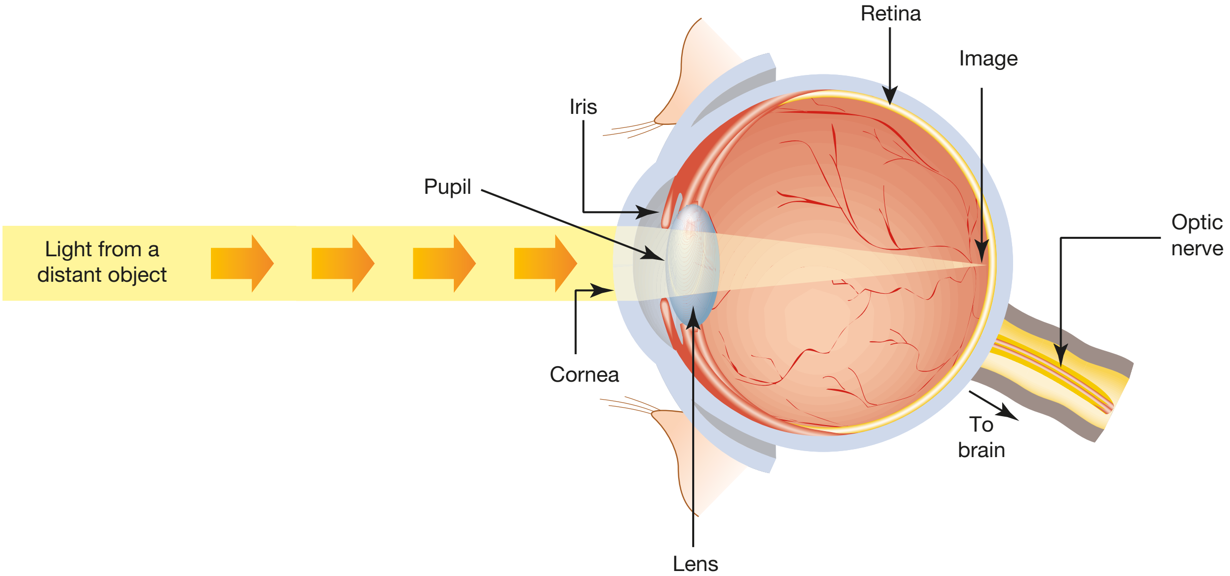
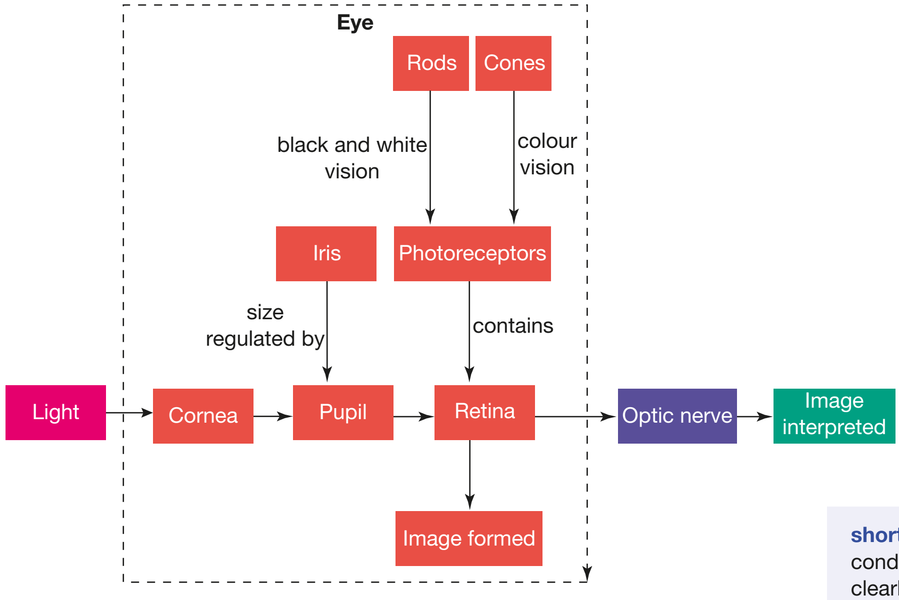
FIGURE 2.29 There are a number of structures within your eyes that function together so that you can detect and respond to light.



Short-sightedness (myopia) and **long-sightedness (hyperopia)** are conditions in which a sharp image is not received on the retina. In these cases, the image can be sharpened by using artificial lenses such as those in glasses.

Although your eye receives light and produces an image of what you see, it is your brain that interprets and makes sense of the image. The photoreceptors in the retina respond to the light stimuli by sending signals to your **optic nerve,** which then forwards them to your brain for interpretation. The process can is outlined in figure 2.30.

FIGURE 2.30 Flow chart of how cells and nerves work together to allow us to see



short-sightedness (myopia) the condition of not being able to see clearly things that are far away

long-sightedness (hyperopia) the condition of not being able to see clearly things that are close

optic nerve large nerve that sends signals to the brain from the sight receptors in the retina

on Resources

Weblink The human eye

elog-0631

INVESTIGATION 2.3

Dissection of a mammal's eye

Aim

To investigate the structure of an eye

CAUTION

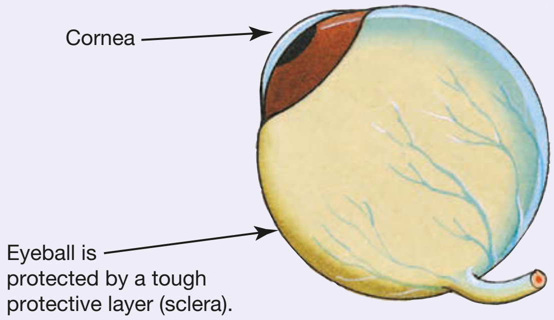
Handle dissecting instruments with care and ensure they are placed in a sterilising solution after use. Wear safety glasses and disposable gloves throughout the dissection and wash your hands thoroughly at the end.

Materials

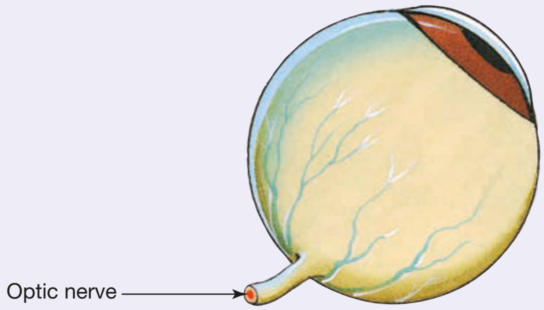
- bull's eye or similar
- dissection board
- newspaper
- paper towelling
- scalpel or razor blade
- safety glasses
- forceps
- stereo microscope
- water
- disposable gloves

Method

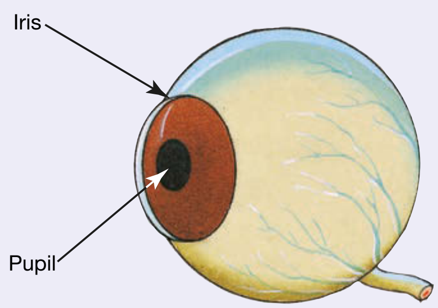
1. Put on safety glasses just in case any of the aqueous or vitreous humour squirts out at you. Aqueous and vitreous humour are jelly-like liquids that give eyes their shape.
2. Carefully place the bull's eye on a dissection board covered with newspaper and paper towelling. Place bull's eye on dissection board covered with newspaper. Locate the transparent skin of the cornea.
   Draw and label the structures of the bull's eye before and after your dissection. (Use the diagrams provided to help you to label your drawing.)



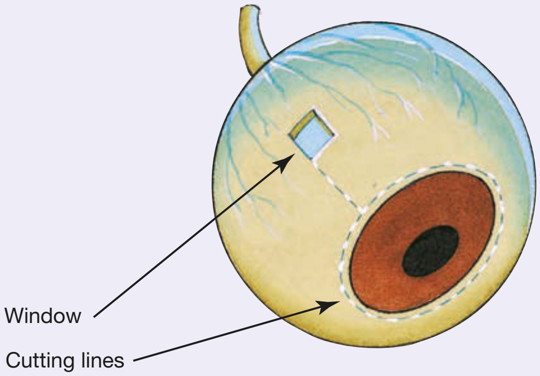
3. Locate the optic nerve. It is a hard, white, solid tube at the back of the eye. You may have to remove some fat to see it. Add descriptive comments to your labels as you make your observations throughout this activity.



4. Look at the coloured part of the eye (iris) and the black part in the centre (pupil).



5. Cut a small window in the eyeball. Be careful that the vitreous humour does not run out. Starting from this window, cut forward and around the iris. Record your observations regarding the toughness of the sclerotic coating.



6. From this window, cut towards and then all the way around the iris so that you have cut the eye into two parts.
7. Lift off the top part of the eye and examine the iris.
8. Remove the lens with forceps and see if you can read the print on the newspaper through it.
9. Use water to rinse out the jelly-like material (humour) from inside the eye and examine the retina. Record your observations.
10. Follow your teacher's instructions regarding the cleaning of equipment and disposal of the dissected eye.

Results

1. Draw labelled diagrams of the eye before and after the dissection.
2. What is the black part in the middle of the iris?
3. What did you observe when you looked at the newspaper through the lens?
4. What did the retina look like? Could you find the optic nerve?

Discussion

1. What does the diaphragm in a microscope do?
2. Which part of the eye does the diaphragm in a monocular microscope most resemble?
3. Summarise your findings in a table.

Conclusion

Write a conclusion about your observations of the structure of the eye.

ACTIVITY: In the dark

Investigate the effect of light intensity on the iris of a human eye.

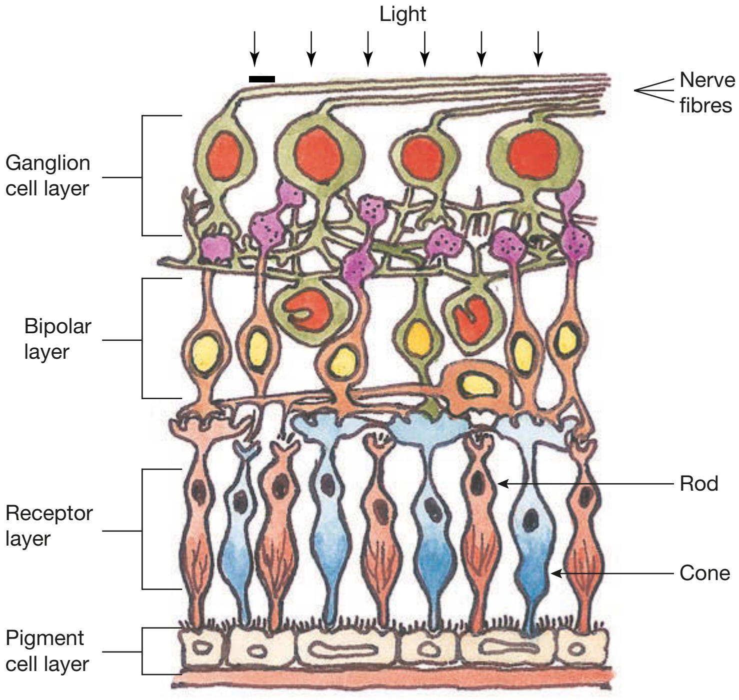
- Cup your hands loosely over both eyes so that you cannot see anything but your hands. Keep your eyes open. Look at the insides of your hands.
- After about one minute, have your partner look carefully at your pupils.

1. What happens to the iris as your hands are removed?
2. Explain your observations.

Black and white or colour?

Why do you see in black and white at night and in colour during the day? It is because of rods and cones. These are two different types of photoreceptors located in your retina. Rods are more sensitive to light and allow you to see in black and white in dim light. Cones are responsible for colour vision, are less sensitive to light and operate best in daylight. At night, there is not enough light for your cones to sense colour.

FIGURE 2.31 The receptor cells in the retina respond to brightness and colour.

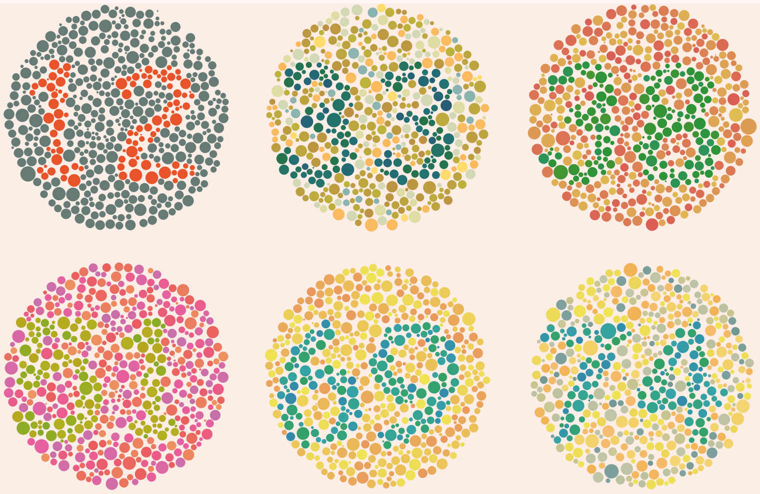


CASE STUDY: Colour blindness

Are you colour blind? **Colour blindness** is an inherited condition that is generally more common in males; however, rarely females can also be colour blind, due to the way in which the condition is inherited. There are also different types of cones. If you have a deficiency of one or more of these it may mean that you find it difficult to see a particular colour or combinations of colours.

colour blindness an inherited condition, more common in males, in which a deficiency of one or more of the different types of cones may mean that you find it difficult to see a particular colour or combinations of colours

FIGURE 2.32 Can you see the different numbers in the Ishihara test? If not, you may be colourblind.



2.4.5 Hearing receptors

The ear is your sense organ that detects sound. The steps involved in the detection of sound and the process of hearing is:

1. Sound travels by waves, which are vibrations in the air.
2. When the air inside your **ear canal** vibrates, it causes your **eardrum** to vibrate at the same rate.
3. Three tiny bones known as **ossicles** in your **middle ear** receive this vibration from your eardrum and then pass it to your inner ear.
4. Inside your inner ear, thousands of tiny hairs attached to nerve cells of the snail-shaped **cochlea** detect the vibration and send a message to your brain via your **auditory nerve**.
5. Your brain interprets the message as hearing sounds.

FIGURE 2.33 An electron micrograph of hair cells in the cochlea

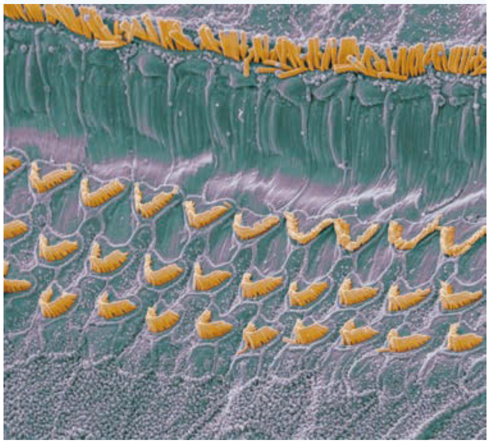


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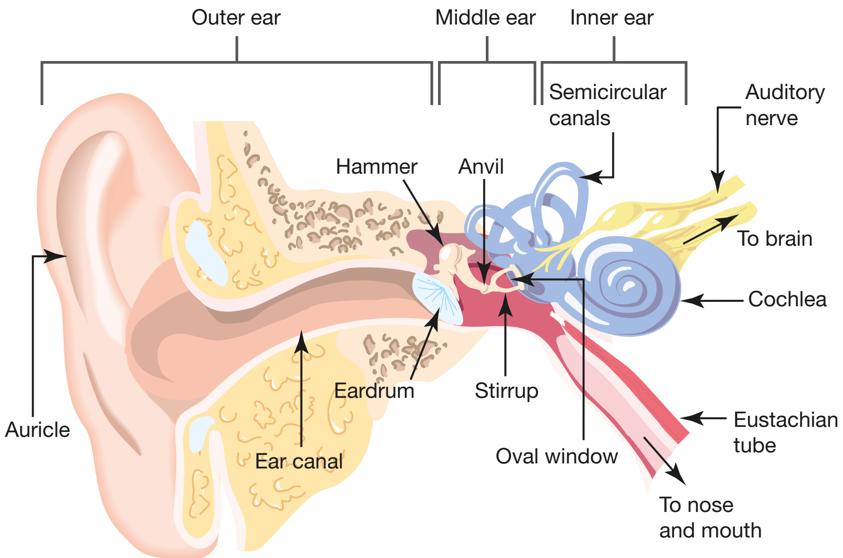
FIGURE 2.34 Your ear contains specialised structures that help you to detect sound.



ear canal the tube that leads from the outside of the ear to the eardrum

eardrum a thin piece of stretched skin inside the ear that vibrates when sound waves reach it

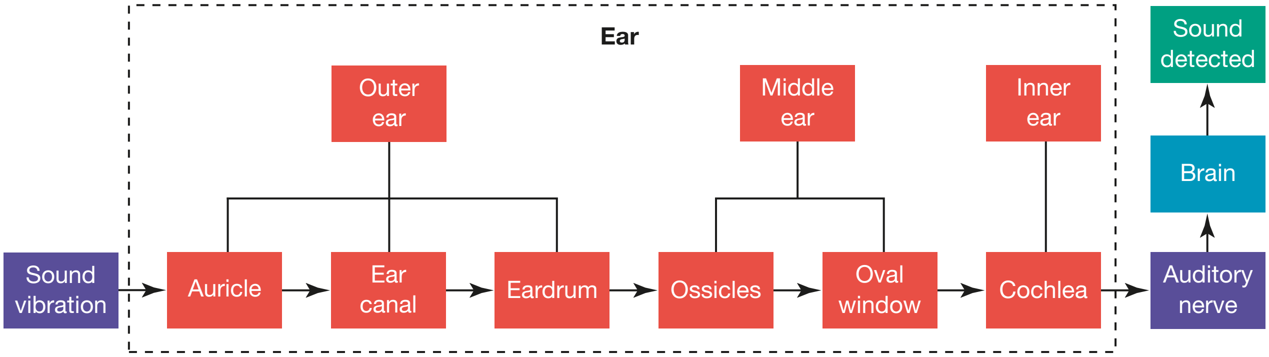
ossicles a set of three tiny bones that send vibrations from the eardrum to the inner ear

middle ear the section of the ear between your eardrum and the inner ear, containing the ossicles

cochlea the snail-shaped part of the inner ear in which receptors are stimulated

auditory nerve a large nerve that sends signals to the brain from the hearing receptors in the cochlea

FIGURE 2.35 Flow chart of the steps that allow us to hear



2.4.6 Taste receptors

The tongue is your sense organ for taste. It was once thought tastebuds in different regions of your tongue could detect particular flavours such as salty, sweet, sour, bitter and savoury (figure 2.36). However, new scientific discoveries have disproved this model and it has now been replaced with a new model to explain how we gain our sense of taste.

In the new model, **tastebuds** located within bumps called **papilla** across your tongue have the ability to sense all flavours. This is because each of these tastebuds contains taste cells with receptors for each of type of flavour.

Hardwired for flavour

Our brains are wired so that we enjoy sweet, savoury and salty foods so that we can obtain the energy, protein and nutrients that we need to survive. However, mass-produced foods are often packed with high amounts of sugar and salt. This has resulted in our sense of taste increasing our chance of suffering from conditions such as diabetes, heart disease and obesity.

Researchers have discovered tiny compounds that can magnify the taste of foods, so that they can taste saltier and sweeter than they really are. The use of these taste enhancers could lead to reduced sugar, salt and monosodium glutamate (MSG) being added to foods, and fewer taste-related diseases.

FIGURE 2.36 This model of taste is now obsolete.

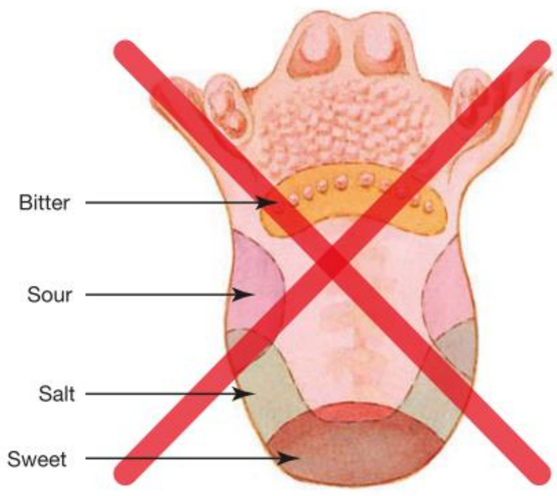


FIGURE 2.37 Tastebuds containing chemoreceptors (as shown here), which are sensitive to particular chemicals

on Resources

eWorkbook Skin (ewbk-5109)

assesson Additional automatically marked question sets

tastebuds nerve endings located in your tongue allowing you to experience taste

papilla bumps on your tongue that are thought to contain tastebuds

ACTIVITY: Unami

Historically, we have classified taste as four main types: sweet, salty, bitter and sour. Recent findings suggest a fifth basic taste, known as unami. Find out what unami is and create a poster outlining the five different basic tastes, including common foods in each category.

2.4 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. State the purpose of the sense organs.
2. Complete the following table:

TABLE Sense organs, stimuli and types of receptors

Sense organs	Stimuli	Types of receptors
		Photoreceptor
Ear		
	Smell	
Tongue		
	Touch	

3. Match each location to the type of receptor.

Location	Receptor
a. Tastebuds in mouth	A. Photoreceptor
b. Hot and cold receptors in skin	B. Mechanoreceptor
c. Rods and cones in the retina	C. Thermoreceptor
d. Hairs in the cochlea of ear	D. Chemoreceptor

4. Identify the location and function of the:
   a. optic nerve   b. olfactory nerve.

Apply and analyse

5. Describe the difference, relationship and function between:
   a. the pupil and iris in the eye   b. rods and cones in the eye.
6. In which part of the human body is an observed image:
   a. formed   b. interpreted
7. If cats have rods, but no cones, what does that mean in terms of how they see the world?
8. Suggest a reason why we are 'hardwired for flavour'.
9. Suggest how the discovery of taste enhancers may reduce the chances of getting 'lifestyle' diseases such as some types of diabetes, heart disease and obesity.

Evaluate and create

10. SIS Describe the new model that is used to explain the involvement of our tongues in the sensation of taste. How is this different to the previous model?
11. Construct a flow chart or mind map that shows structures involved in:
    a. smell   b. vision   c. sound.

12. Suggest why:
    a. the thickest part of your skin is on the soles of your feet
    b. some parts of your skin, such as the back of your hand, are more sensitive to heat than others?
13. How do movement receptors receive a sensation of movement when they are well below the surface of the skin?
14. SIS Olfactory receptor cells are important to enable us to smell things. A human has about 40 million, whereas a rabbit has 100 million and a dog has 1 billion! What effect might this difference have on the chances of survival for these animals?

Fully worked solutions and sample responses are available in your digital formats.

2.5 The brain

LEARNING INTENTION

At the end of this subtopic you will be able to explain the parts and functions of the brain.

2.5.1 What is in your brain?

The average brain weighs around 1.5 kilograms and is made up of about 80 per cent water, 10 per cent fat and 8 per cent protein. Although our brains contain about a billion brain cells, only about 10 per cent are active neurons (nerve cells); the remaining brain cells are there to nourish and insulate the neurons. These neurons can grow extensions called dendrites, which reach out like branches on a tree, allowing communication between other neurons. This communication is very important in relaying information about your environment and deciding what to do with it. Refer back to section 2.3.2 to review neurons.

FIGURE 2.38 Various MRI images of the brain

More than just a bag of chemicals!

Your brain is more than just a mix of chemicals and cells. It is the control centre of all of your body's functions and is responsible for:

- intelligence
- creativity
- perceptions
- conscious reactions
- emotions and memories.

It can be said that your brain is at the wheel, steering your body's systems so that it continues to function correctly, whether it's remembering the taste of chocolate, working out a crossword puzzle, controlling your heartbeat or monitoring the glucose level in your blood.

When you think, you are using your brain. Another name for thinking is **cognition**. You also 'feel' with your brain. Happiness, sadness and anger are examples of feelings or emotions that are interpreted by your brain. Your brain also interprets messages about your internal and external environments, and plays a key role in regulating processes that keep you alive.

2.5.2 How the brain is organised

Your brain cells are organised into different areas within your brain. Although they may have different functions, they communicate and work together to keep you alive. There are a number of different models that are used to describe the structure of the human brain.

From back to front

- Your **hindbrain** is really a continuation of your spinal cord. It develops into the **pons** and cerebellum, and the **medulla oblongata** (medulla).
- Extending through your hindbrain and midbrain is a network of fibres called the **reticular formation** — a network of neurons that opens and closes to increase or decrease the amount of information that flows into and out of the brain. The reticular formation helps regulate alertness (from being fully awake or deeply asleep), motivation, movement and some of the body's reflexes (such as sneezing and coughing).
- The **forebrain** develops into the cerebrum, **cerebral cortex** (outer, deeply folded surface of the cerebrum) and other structures such as the **thalamus**, hypothalamus and **hippocampus**.

cognition another name for thinking or mental activity

hindbrain a continuation of the spinal cord

pons part of the brain involved in regulating sleep, arousal and breathing, and coordinating some muscle movements

medulla oblongata (medulla) a part of the brain developed from the posterior portion of the hindbrain

reticular formation a network of neurons that controls the amount of information that flows into and out of the brain

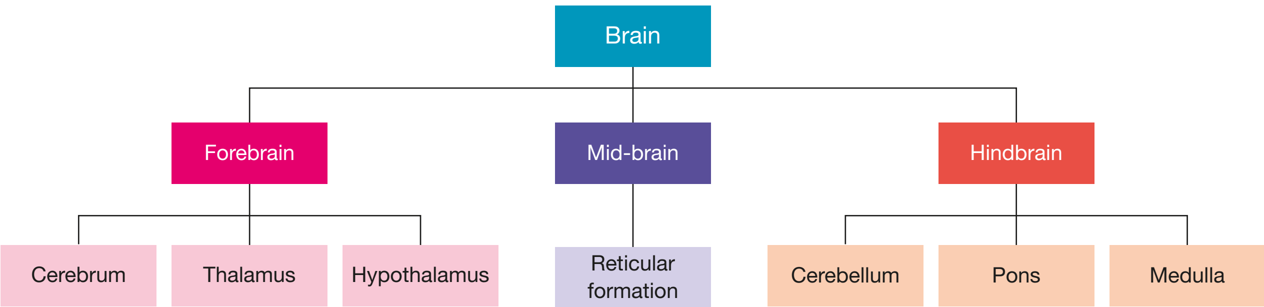
forebrain consists of the cerebrum, cerebral cortex, thalamus and hypothalamus

cerebral cortex the outer, deeply folded surface of the cerebrum

thalamus part of the brain through which all sensory information from the outside (except smell) passes before going to other parts of the brain for further processing

hippocampus part of the brain with a key role in consolidating learning, comparing new information with previous experience, and converting information from working memory to long-term storage

FIGURE 2.39 Components of the human brain



Brain stem or medulla

Not all actions in your body require conscious thought. These are called involuntary actions and you don't need to think about them for them to occur. Breathing, heartbeat, blood pressure, coughing, vomiting, sneezing and salivating are all examples of involuntary actions controlled by your **brain stem**.

Your brain stem (or medulla) is located between your spinal cord and your cerebrum. If this vital structure is damaged, death may result.

brain stem the part of the brain connected to the spinal cord, responsible for breathing, heartbeat and digestion

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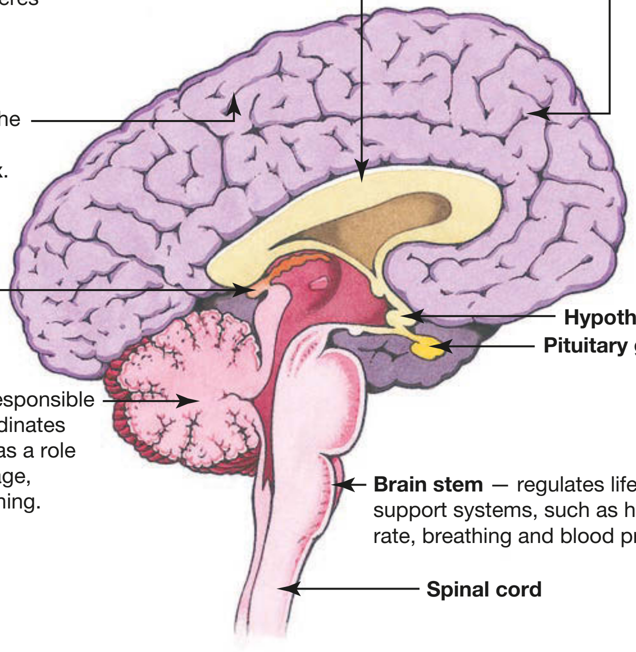
FIGURE 2.40 The human brain



Cerebellum

Your **cerebellum** is located near the brain stem, underneath the cerebrum. Although it takes up only about 10 per cent of your brain's volume, the cerebellum contains over half of all of your brain's neurons. Your cerebellum has key roles in posture, coordination, balance and movement. Current research also suggests that it may also be involved in memory, attention, spatial perception and language.

The word *cerebellum* means 'little brain' in Latin and that's just what it looks like. There are two halves (or hemispheres), one for each side of the brain. Each of these hemispheres consists of three lobes. There is a lobe that receives sensory input from your ears to help you to maintain your balance. Another lobe gets messages from your spinal cord to let your brain know what some other moving parts of your body are up to. There is even a lobe that communicates with your cerebrum, the thinking part of your brain.

Cerebrum

The **cerebrum** is the largest part of the brain and makes up about 90 per cent of your brain's total volume. The cerebrum is responsible for higher-order thinking (such as problem solving and making decisions) and controls speech, conscious thought and voluntary actions (actions that you control by thinking about them). The cerebrum is also involved in learning, remembering and personality.

The cerebrum is made up of four primary areas called lobes. Each of these lobes is associated with particular functions.

You can use a piece of paper to model how the cerebrum can fit into such a small area. If you screw up the piece of paper so that it is roughly the size of your fist you can see how the cerebrum, with its large surface area, can fit into a small area within your skull. Its many wrinkles and folds are the reason that only about one-third of this structure is visible when you look at the outside of a brain.

cerebellum the part of the brain that controls balance and muscle action

cerebrum the largest part of the brain responsible for higher order thinking, controlling speech, conscious thought and voluntary actions

on Resources

Video eLesson Willis and the brain (eles-1783)

SCIENCE INQUIRY: Using analogies and metaphors to understand the brain

Using analogies and metaphors can be very useful in helping you to connect information that you already know to new information. Analogies are similarities between two or more things on which a comparison may be based. Metaphors are figures of speech in which something is spoken of as if it were something else. An example of an analogy is 'a child's brain is like a sponge.' This provides a framework of known ideas to relate to new ideas.

While analogies and metaphors and models can be very useful in your learning, they also have limitations. The more we find out about the brain, the less suitable a previously used metaphor or analogy may be. Examples of other metaphors that have been used for the brain include a cloud server, a toolbox and an ecosystem in a jungle! These analogies often reflect the most current technological innovation of the time.

Did you notice examples of analogies and metaphors mentioned throughout these pages? How effective have they been in helping you 'get a handle' on new information about the brain?

2.5.3 Left and right — Two brains in one?

Your cerebrum is divided into two **cerebral hemispheres** — the right cerebral hemisphere (mainly responsible for the left side of your body) and the left cerebral hemisphere (mainly responsible for the right side of your body). While each hemisphere is specialised to handle different tasks, they work together as an integrated whole, communicating with each other through a linking bridge of nerve fibres called the **corpus callosum**.

cerebral hemispheres the left and right halves of the brain

corpus callosum a bridge of nerve fibres through which the two cerebral hemispheres communicate

ACTIVITY: Brain dominance

Although the left and right cerebral hemispheres have specialised functions, they communicate with each other. Depending on the task, you can switch from one side of your brain dominance to the other a number of times each day.

Work out whether you are left- or right-brain dominant.

a. For each hemisphere, give a mark between 1 and 5 (1 being strongly disagree and 5 being strongly agree) for each of the statements you relate to in figure 2.41.

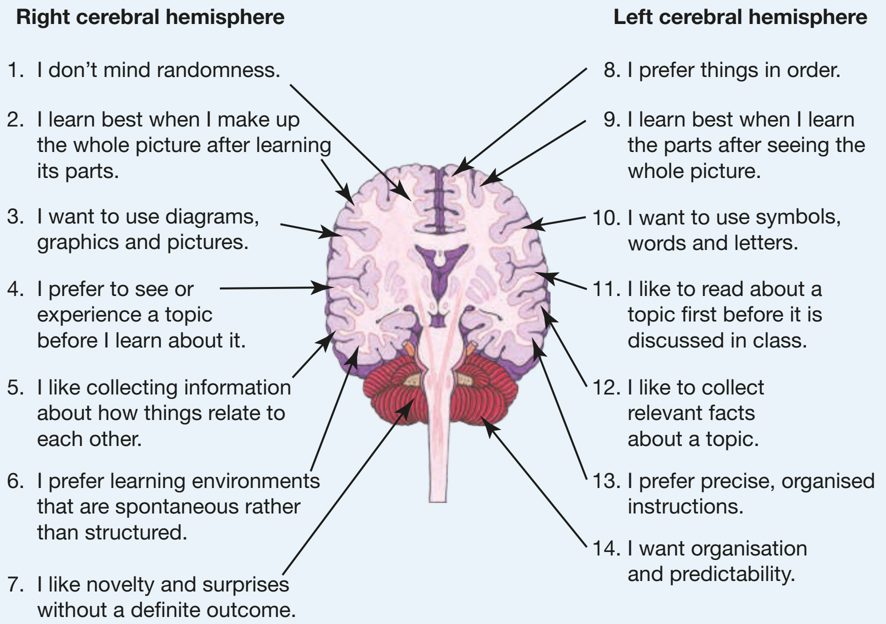
b. Add up the total score for each side. In which hemisphere of the brain did you score higher? What about the majority of your class?

c. What does this mean in terms of your learning?

Although each cerebral hemisphere processes information differently, they are both involved in putting together the total picture of what you sense around you. During your learning, it is important to employ learning activities that utilise the strengths of both hemispheres (even if it can feel a little uncomfortable sometimes). This will allow you to focus on 'whole-brained' learning.

Like your thumbprint, your brain is unique. Not only may it be a different size and weight from your friends, but the learning connections between cells in your brain are different. These connections are made as a result of your experiences and this forms your own personal 'cognitive map', which can change over time as you build up more experiences. This difference in our brain's 'internal wiring' can explain why people at the scene of the same accident can have such different eyewitness reports.

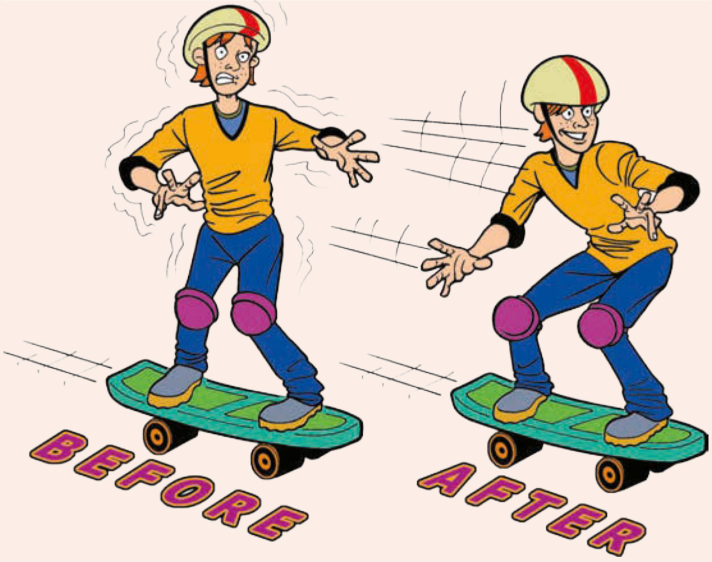
FIGURE 2.41 Each hemisphere has specialised functions



CASE STUDY: Learning new skills

When you start learning a new skill, you have to think carefully about what you are doing. Once you have got the hang of it, your cerebellum takes over from your thinking context to tell your body what to do. Research has shown that when the cerebellum is in charge, you can move faster and are less clumsy. Other research suggests that long-term memory traces for motor learning are located in your cerebellum and that movement may help your thinking because of increased signals travelling between your cerebrum and cerebellum.

FIGURE 2.42 Learning new skills requires conscious thought.



2.5.4 Tasty words and colourful letters?

A small percentage of the population have their senses crossed and associate letters with a flavour, numbers with a gender and sounds with colour. This condition is known as **synaesthesia**. It has been likened to receiving information in one sense and it triggering an experience in another. So while you might hear music, the sounds trigger seeing particular colours! There are thought to be at least 54 documented types of this condition. Currently there is exciting research being conducted in this area, investigating how people with this condition form and remember memories. Some of these investigations involve the use of **functional magnetic resonance imaging (fMRI)** to get a 3-dimensional image of the brain so that the areas of the brain that are activated during different mental tasks can be recorded.

synaesthesia a condition in which a sensation is produced in one physical sense when a stimulus is applied to another

functional magnetic resonance imaging (fMRI) a type of specialised MRI scan used to measure the change in blood flow related to neural activity in the brain or spinal cord

FIGURE 2.43 Someone with synaesthesia might perceive certain letters and numbers as they are shown here.

SYNAESTHESIA
0123456789

elog-0633

INVESTIGATION 2.4

Dissection of a mammal's brain

Aim

To investigate the structure of the brain

CAUTION

Handle dissecting instruments with care and ensure they are placed in a sterilising solution after use. Wear safety glasses and disposable gloves throughout the dissection and wash your hands thoroughly at the end.

Materials

- a semi-frozen sheep's brain
- dissecting board
- dissecting instruments (scalpel, forceps, scissors)
- plastic ruler
- paper towel
- disposable gloves

Method

1. Place the brain so that the cerebral hemispheres are at the top of the board and the brain stem is at the bottom.
2. Identify the external features of the brain: the cerebral hemispheres, cerebellum and brain stem.
3. Use your forceps and try to lift the meninges (membranes protecting the brain). You may be able to observe the cerebral fluid between these membranes and the hemispheres.
4. Carefully observe the overall appearance of each structure and, using a plastic ruler, measure its size (length, width and height). Include this information in a table in the results section.
5. Draw a diagram of the sheep's brain, labelling the external features.

6. Using your scalpel, cut the brain in half between the right and left hemispheres, and separate the two cerebral hemispheres.

7. Draw a cross-section of the brain. Be sure to label it!
8. Now make a second cut down through the back of one of the hemispheres to see inside the cerebellum and brain stem.

Results

1. Construct a table with the headings shown below and record your observations from the dissection.

TABLE Observations of different brain structures

Brain structure	Appearance			
	Colour	Texture	Other features	Size
Cerebrum				
Cerebellum				
Brain stem				

2. Sketch the sheep's brain, labelling the external features. On your diagram, identify and label the part of the brain that controls the sheep's:
   a. heart rate
   b. balance required for walking
   c. ability to locate its lamb.
3. Sketch a cross-section of the sheep's brain.

Discussion

1. a. Which structures contained the grey and white matter?
   b. Find out why these structures are different colours.
2. Which part of the sheep's brain is the biggest? Is this the same pattern in human brains?
3. The brain is usually protected by a bony skull. It is also covered with three layers of connective tissue called meninges and surrounded by cerebral fluid. Suggest how the meninges and cerebral fluid help protect the brain.
4. Identify strengths and limitations of your investigation of the brain and suggest improvements.

Conclusion

Summarise your findings of the structures in the brain.

on Resources

eWorkbook	The brain (ewbk-5113)
Weblink	Neuroscience
assess on	Additional automatically marked question sets

2.5 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

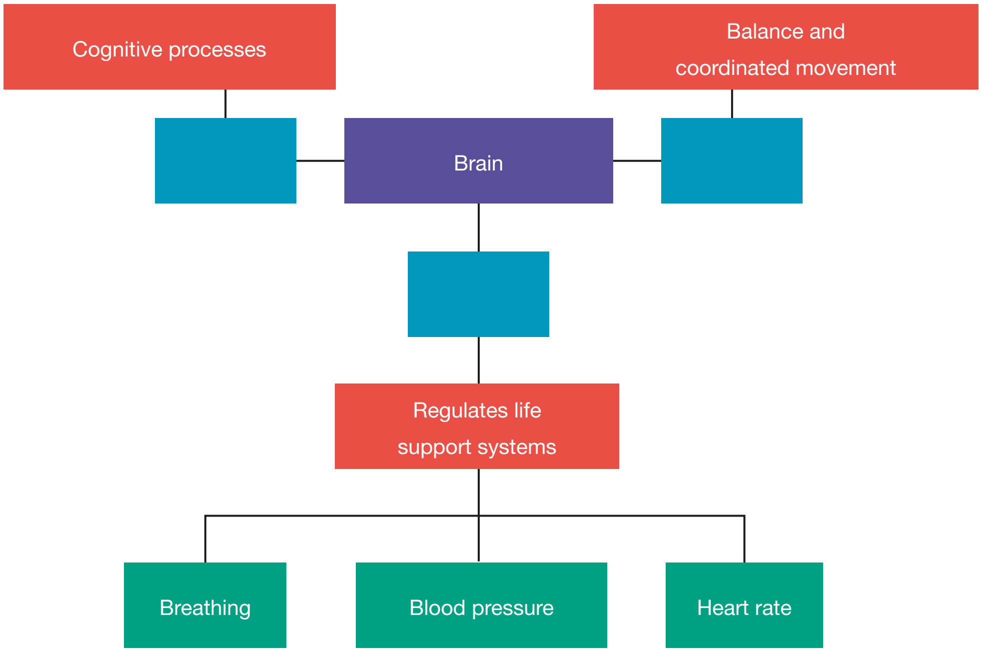
LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 5	Questions 3, 6, 9	Questions 4, 7, 8

Remember and understand

1. Name the organ that has been described as the control centre of your body.
2. Identify the part of your brain that:
   a. takes up the greatest volume
   b. regulates heartbeat, breathing and blood pressure
   c. generates the most complex thoughts
   d. coordinates movement
   e. manages communication between left and right hemispheres.
3. Explain the roles of the following components of the brain:
   a. cerebrum b. pons c. medulla oblongata d. hippocampus.
4. Distinguish between:
   a. cerebrum and cerebellum
   b. left and right cerebral hemispheres
   c. cerebrum and cerebral cortex.

Apply and analyse

5. Use analogies to describe the appearance of the:
   a. brain b. cerebrum c. cerebellum.
6. Copy the cluster map shown and insert ‘cerebrum’, ‘cerebellum’ and ‘brain stem’ into their appropriate location.



7. a. Explain the difference between the cerebral hemispheres.
   b. Outline how these hemispheres are able to work together.

Evaluate and create

8 SIS *Brains react to music like a drug*. This was a claim made in the media in 2011. It was based on a scientific study that used PET (positron emission tomography) and fMRI brain scans to record brain activity of volunteers while they listened to their favourite piece of music. The PET scan detected a release of dopamine (a neurotransmitter responsible for feeling a sense of reward and pleasure) in their brains and the fMRI scan showed increased blood flow to the emotional response areas.

a. For this investigation suggest:
   i. a hypothesis
   ii. the dependent variable(s) and independent variable
   iii. an appropriate control group
   iv. controlled variables.

b. Find out more about similar investigations. Is the media claim supported by your findings? Explain.

9. SIS The table shows the brain size as a percentage of body mass for a number of animals. Use this data, your own knowledge, and other resources (if required) to answer the following questions.

a. Construct a graph using the information in the table.
b. Comment on any trends or patterns in the graph.
c. Suggest and discuss two possible explanations for the observed patterns.
d. Suggest a relevant hypothesis that could be investigated.
e. Formulate three questions about how the data was collected (method used).
f. Suggest three relevant questions that could be further investigated.

TABLE The brain size as a percentage of body mass for different animals

Animal	Brain size as % of body mass
Mouse	10
Chimp	0.8
Elephant	0.1
Dolphin	1
Cat	1
Human	2

Fully worked solutions and sample responses are available in your digital formats.

2.6 The endocrine system — slow control

LEARNING INTENTION

At the end of this subtopic you will be able to explain how the endocrine system controls the body functions through hormones released by various glands.

2.6.1 Helpful hormones

Thirsty? Too hot or too cold? Feeling different or noticing changes in how you look, feel or act? Chemicals in your blood not only help to keep you balanced, but are also very important in controlling and coordinating your growth and development.

Your nervous system is not the only means of controlling and coordinating activities in your body. Your endocrine system uses chemical messengers called hormones. They are produced in your endocrine glands and are released directly into your bloodstream. Although hormones are carried to all parts of your body, only particular cells have receptors for particular hormones. It is a little like radio signals, which are sent out in all directions but picked up only by radios attuned to a particular signal. These target cells have receptors that respond to the hormones carried through your body and respond in a particular way.

eles-2633

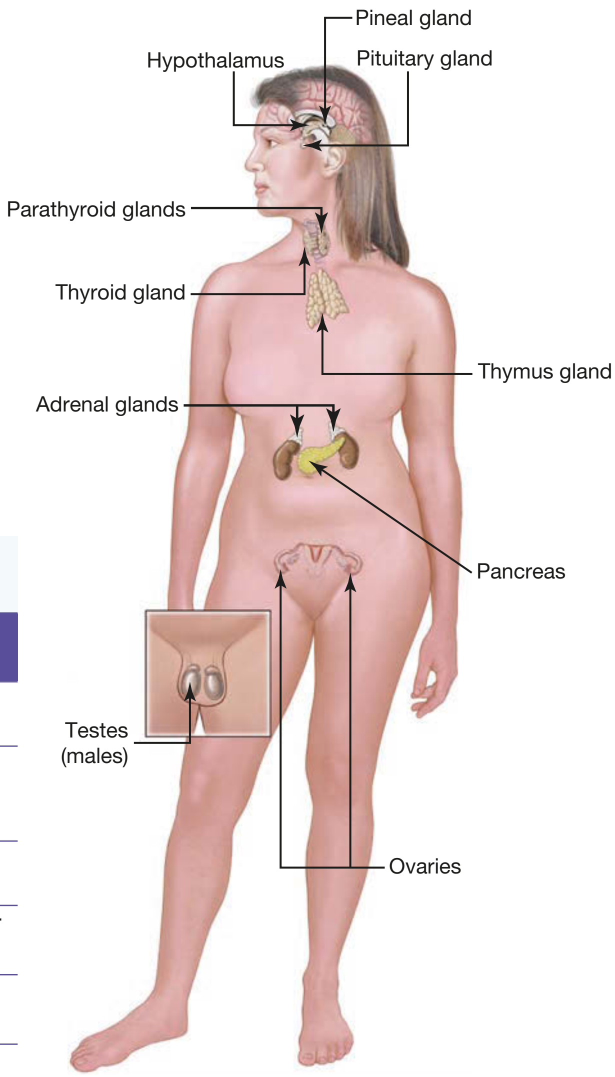
Your endocrine system is composed of **endocrine glands** that secrete chemical substances called hormones into the bloodstream. These chemical messages are transported throughout the circulatory system to specific target cells in which they bring about a particular response.

Hormones control and regulate functions such as metabolism, growth, development and sexual reproduction. Like the nervous system, the endocrine system detects a change in a variable, and often acts using a *negative feedback* mechanism to counteract the initial change. The endocrine system also works with the nervous system to regulate your body's responses to stress. The effects of the endocrine system are usually slower and generally longer lasting than those of the nervous system.

TABLE 2.5 Examples of endocrine glands and their hormones

Endocrine gland	Example of hormone released	Response
Thyroid	Thyroxine	Raises basal metabolic rate
Adrenal	Adrenaline	Increases heart rate and blood pressure in times of stress
Pancreas	Insulin	Lowers blood glucose levels
Pituitary	Anti-diuretic hormone (ADH)	Reabsorption of water in kidneys
Ovaries	Progesterone	Controls menstrual cycle and pregnancy
Thymus	Thymosin	Stimulates the production of white blood cells to fight infection

FIGURE 2.44 The human endocrine system



2.6.2 Endocrine glands in your brain

Although endocrine glands are located in various parts of your body, three major glands are located in the brain:

1. **pituitary gland** is often referred to as your 'master gland' because it controls many other endocrine glands, stimulating them to release their own hormones. For example, your thyroid gland, ovaries and testes are all controlled by hormones released by this endocrine gland. Hormones released by the pituitary gland can control water balance, growth, development and reproduction-related processes.
2. hypothalamus sends hormones to the pituitary gland to control its release of hormones to other endocrine glands. It also releases hormones that control body temperature, growth, sex drive, thirst, hunger and sensations of pleasure and pain. The hypothalamus links your nervous system to your endocrine system and is involved in reflex actions such as those involved in the beating of your heart and breathing.
3. **pineal gland** produces the hormone melatonin, which controls body rhythms such as waking and sleeping.

endocrine glands organs that produce hormones, which are released into the bloodstream

pituitary gland a small gland at the base of the brain that releases hormones

pineal gland gland that produces the hormone melatonin, which can make you feel drowsy

2.6.3 Keeping balance

Keeping warm

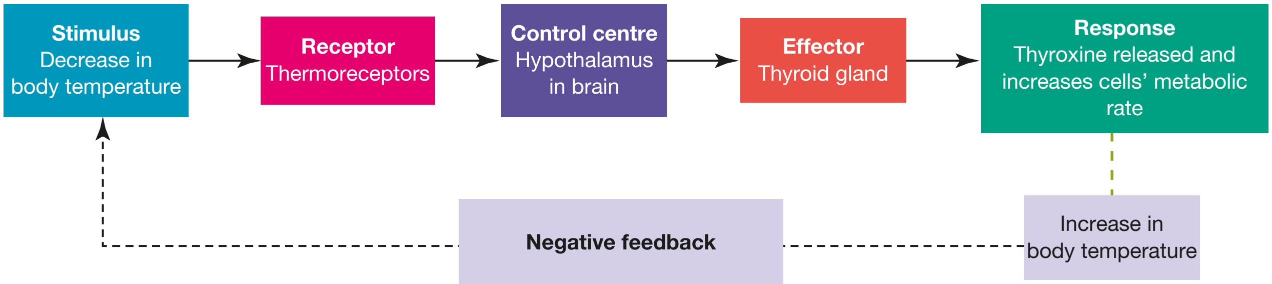
Negative feedback, which was introduced in subtopic 2.2, helps our body to keep its internal conditions stable so that you can function effectively. An example of this is if your body temperature is too low.

1. The decrease in body temperature acts as the stimulus, which is detected by thermoreceptors in your body.
2. This message is taken to the hypothalamus, which activates warming mechanisms.
3. One of these mechanisms involves the **thyroid gland**. It responds by secreting the hormone thyroxine, which increases the metabolic rate of cells, releasing heat to warm you.
4. Raising body temperature reduces the need for the hypothalamus to direct the thyroid gland to secrete thyroxine.

thyroid gland a small gland in the neck that helps regulate metabolism and growth

Negative feedback is used by the endocrine system to regulate body temperature and is referred to as thermoregulation (figure 2.45). This process also involves the nervous system, as discussed in section 2.2.5.

FIGURE 2.45 Negative feedback loop of thermoregulation

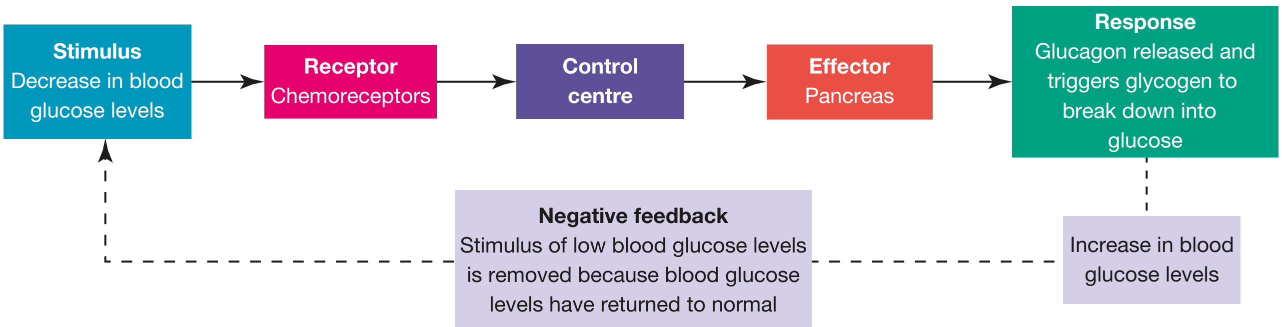


Sweet control

Negative feedback is also used by your endocrine system to regulate blood glucose levels.

1. After you have eaten a lot of sugary food, your blood glucose levels increase.
2. This rise is detected by cells in your pancreas, which then secretes the hormone insulin.
3. Insulin travels in the bloodstream and specific target cells in your liver and muscles respond by increasing the uptake of glucose into the cells and the conversion of glucose into glycogen, which is then stored.
4. The result is that blood glucose levels return to their 'normal' levels (figure 2.46).

FIGURE 2.46 Negative feedback loop of glucose regulation



If a decrease in blood glucose levels is detected, the pancreas secretes the hormone **glucagon**. This hormone also travels in the blood to the liver and muscle cells, but in this case the response is that glycogen is broken down into glucose. Glucose is released into the blood, increasing blood glucose levels back to their 'normal' levels.

glucagon a hormone, produced by the pancreas, which increases blood glucose levels

luteinising hormone (LH) hormone produced by the anterior pituitary gland that initiates ovulation, the production of progesterone and corpus luteum development in females and in the stimulation of production of testosterone in testes in males

testosterone male sex hormone

Reproductive control

The endocrine system also plays a key role in controlling and coordinating human reproduction and development.

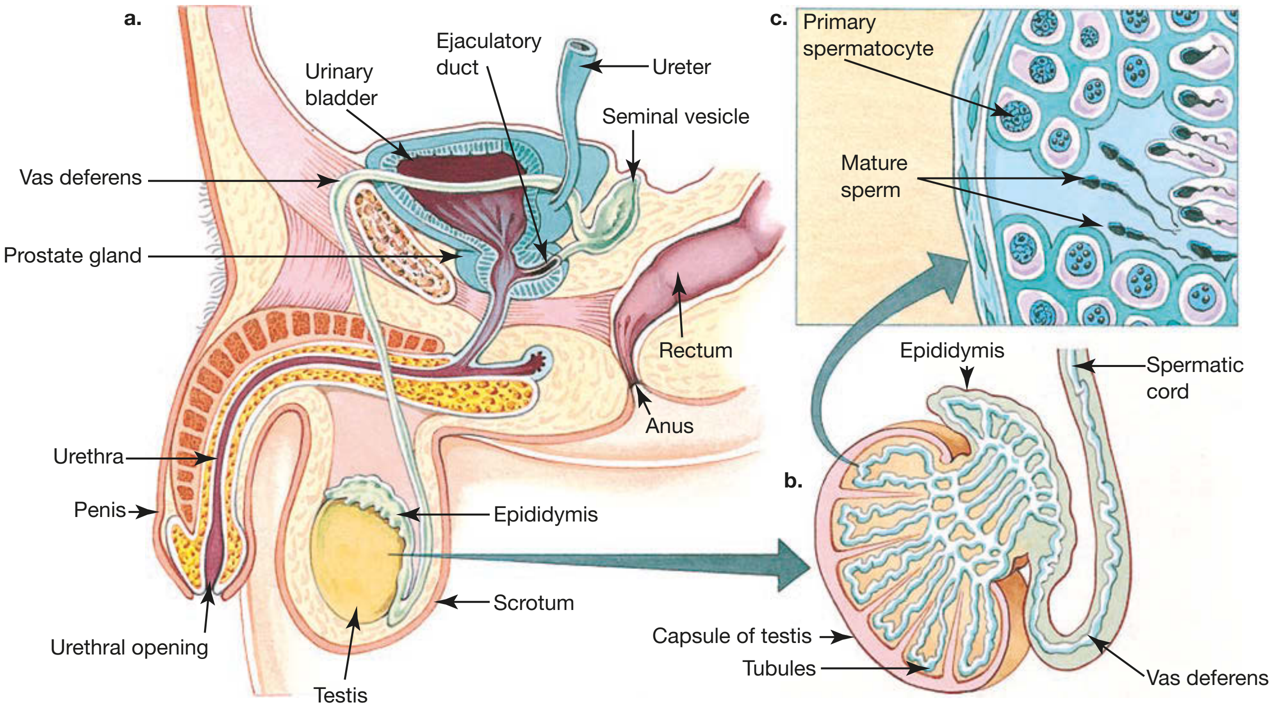
When a male reaches puberty, the endocrine system releases several hormones.

1. The male's pituitary gland secretes **luteinising hormone** (or **LH**).
2. LH acts on his testes to produce another hormone called **testosterone**. An increase in testosterone levels causes sex organs to grow and testes to begin to produce sperm. Other secondary sex characteristics are increased muscle development, changes in voice, muscle and hair growth and hormones.

ewbk-5117

int-3032

FIGURE 2.47 a. The male reproductive system **b.** The internal structure of the testes **c.** An increase in the level of testosterone during puberty triggers the testes to produce sperm cells.



When a female reaches puberty, the endocrine system releases different hormones.

1. The female pituitary gland secretes **follicle-stimulating hormone (FSH)**.
2. FSH then acts on ovaries to stimulate the **follicles** (structure in which the egg develops) to grow.
3. A hormone called **oestrogen** is secreted from the ovaries (and the placenta during pregnancy), which causes the thickening of the lining of the **uterus** to prepare it for a potential fertilised egg.
4. Increased levels of oestrogen also stimulate the hypothalamus to produce more FSH and LH.

follicle-stimulating hormone (FSH) regulates the development, growth and reproductive processes of the body

follicles found in the ovary and contain a single immature ovum (egg)

oestrogen hormone secreted from the ovaries and the placenta with a variety of effects such as inducing puberty changes and thickening of the uterus lining

uterus the organ in which a baby grows and develops

5. Increasing levels of LH cause the follicle to swell. The mature follicle bulges on the surface of the ovary, ruptures, and the **ovum** (unfertilised egg cell) is released from the ovary into the fallopian tube. This process is called **ovulation**.
6. Following ovulation, the empty follicle from which the egg was released becomes a **corpus luteum**. This structure secretes another hormone called **progesterone**.
7. Progesterone continues to prepare the uterine lining for pregnancy.
8. If **fertilisation** does not occur, both the ovum and corpus luteum break down. This causes the progesterone levels to drop and hence the lining of the uterus (endometrium) to break down. Blood and uterine lining are discharged through the vagina in a process called **menstruation**.
9. When progesterone levels drop, the pituitary gland produces FSH and the cycle begins again. These cyclic changes in the ovaries and lining of the uterus as a result of changing hormone levels in the blood are called the menstrual cycle.

ovum female sex cells produced in the ovaries

ovulation the release of an ovum

corpus luteum an endocrine structure that is involved in the production of progesterone

progesterone hormone produced in the ovaries that inhibits ovulation and prepares the lining of the uterus for pregnancy

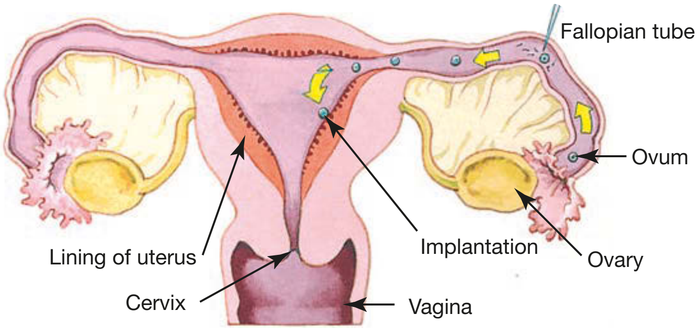
fertilisation fusion of the male sex cell (sperm) and the female sex cell (ovum)

menstruation monthly discharge of blood and other materials from the uterus lining through the vagina (also known as period)

ewbk-5119

int-3032

FIGURE 2.48 The female reproductive system showing the release of an ovum



SCIENCE AS A HUMAN ENDEAVOUR: Using hormones to control reproduction

Hormones can be harnessed to either increase or decrease fertility. There are a number of issues that have been expressed about the production, availability, uses and consequences of these hormones.

Hormones are used as contraceptives for females. Traditionally in pill form, they are now appearing in patches, gels, implants and insertable vaginal rings. There is also a 'morning-before' pill, which can be used as an emergency contraceptive. This pill works by altering the ion content of the woman's reproductive tract for about 36 hours. The changes that it produces make it more difficult for the sperm to swim and hence less likely for them to reach the ovum to fertilise it.

FIGURE: 2.49 Contraceptive pills contain different levels of hormones.

There are also plans to develop contraceptive drugs that target hormone receptors rather than altering hormone levels. These new contraceptives may work by tricking the egg into thinking that it is already fertilised so that it blocks sperm from penetrating it. Other new contraceptives may involve the development of hormones that prevent the fertilised egg from implanting in the uterus.

Scientists are working on developing male contraceptive pills. These are based on combination of androgen and progesterone. Androgen blocks sperm development and progesterone blocks testosterone production. While combinations of these hormones may be used to prevent fertility, there are possible side effects that need to be considered.

In cases of abortion, an alternative to a surgery is the commercially produced hormone RU486 (Mifepristone). RU486 can terminate an early pregnancy by blocking the action of progesterone. This causes the lining of the uterus to break down so that the embryo is unable to implant into it. This pill is less invasive and has fewer side effects than a surgical abortion and it enables termination at a much earlier stage. In Australia, doctors must be a registered prescriber of RU486 to administer it to patients.

DISCUSSION

How might hormone replacement therapy help reduce the effects of menopause in women?

on Resources

Video eLesson Methods of contraception (eles-0127)

eWorkbook The endocrine system (ewbk-5121)

assess on Additional automatically marked question sets

2.6 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 3, 6, 10, 14	Questions 2, 5, 7, 11, 12, 16	Questions 4, 8, 9, 13, 15

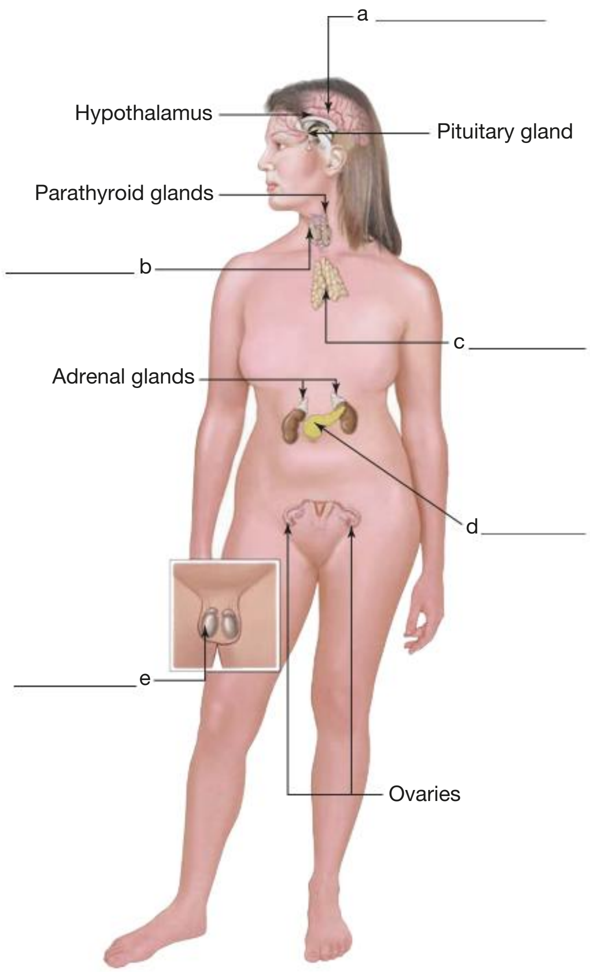
Remember and understand

1. Match the term with its description in the table provided.

Term	Function
a. Anti-diuretic hormone (ADH)	A. Increases blood glucose levels
b. Glucagon	B. Lowers blood glucose levels
c. Insulin	C. Increases metabolic rate of cells
d. Oestrogen	D. Causes testes to produce sperm
e. Progesterone	E. Controls menstrual cycle and pregnancy
f. Testosterone	F. Causes thickening of the uterine lining
g. Thyroxine	G. Causes reabsorption of water in kidneys

2. Identify and describe the three endocrine glands located in your brain.
3. What are hormones, where are they produced and how are they transported through the body?
4. Are all parts of the body affected by a particular hormone? Explain.

5. Label the endocrine system in the figure provided.



6. Identify two ways in which the actions of the endocrine system differ from the nervous system
7. Provide an example of negative feedback that includes the involvement of a hormone.

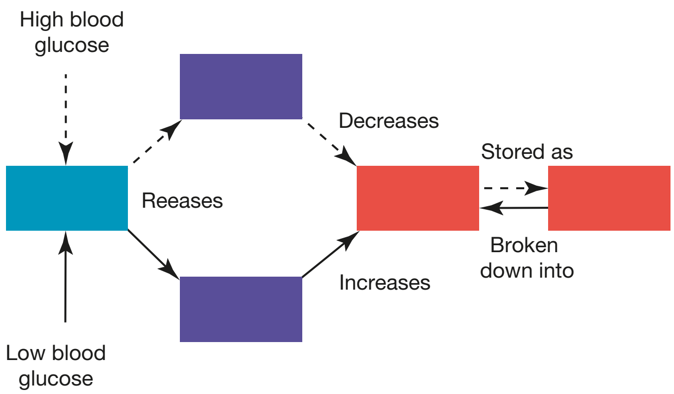
Apply and analyse

8. Distinguish between:
   a. hormones and endocrine glands
   b. menstruation and ovulation
   c. endometrium and uterus
   d. testes and sperm.
9. Describe the relationship between the:
   a. pancreas, liver, glucose, glucagon, glycogen and insulin
   b. pituitary gland, LH, testes, testosterone and sperm
   c. pituitary gland, FSH, ovary, oestrogen, follicles, uterine lining, hypothalamus, LH, ovum, fallopian tube and ovulation
   d. corpus luteum, uterine lining, progesterone and menstruation.
10. How are hormones involved in the balance of water in your body?
11. a. Other than pills, in which forms can hormone-based female contraceptives be used?
    b. Outline how these hormones can be used to prevent fertility.
12. a. Name the two hormones that may be used in a male contraceptive pill.
    b. Outline how these hormones can be used to prevent fertility.

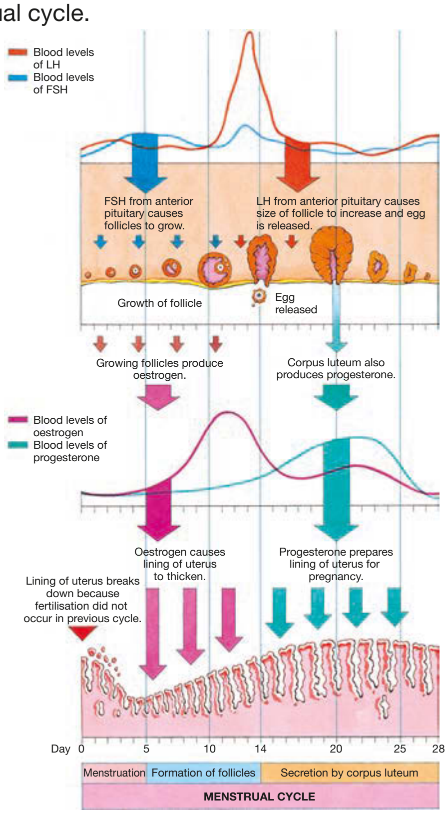
Evaluate and create

13. Male and female fertility patterns are different. Find out the key differences and comment on how they may affect the development and use of effective hormone-based contraceptives.

14. Complete the flow chart to link the listed terms.
- Glucagon
- Insulin
- Pancreas
- Glycogen
- Glucose



15. SIS A synthetic chemical called pyrethrin is increasingly being used in sheep dip. Sheep dipping involves placing sheep in a liquid that acts to remove and protect against external parasites from sheep. It breaks down within a few days, but during that time it can kill many types of invertebrates in the waterways.
   a. Why are sheep dipped?
   b. How could sheep dip reach waterways?
   c. Suggest implications for the deaths of invertebrates on other organisms.
16. SIS Ovulation occurs when the mature follicle ruptures on the surface of the ovary and the ovum is released. Use the graphs provided here to answer the following questions.
   a. Which hormone in the graph is at the highest level just prior to ovulation?
   b. When is ovulation likely to occur?
   c. When is progesterone at its highest levels?
   d. At what stage in the cycle is the endometrium the thickest?
   e. Describe the changes in the concentrations of each of the hormones throughout the menstrual cycle.
   f. Research the changes in the levels of FSH (follicle stimulating hormone) and LH (luteinising hormone) throughout the menstrual cycle.



Fully worked solutions and sample responses are available in your digital formats.

2.7 Plant hormones

LEARNING INTENTION

At the end of this subtopic you will be able to explain how and why plants utilise their own hormones for various functions and how plant hormones can be manipulated by humans and technology.

2.7.1 How plants use hormones

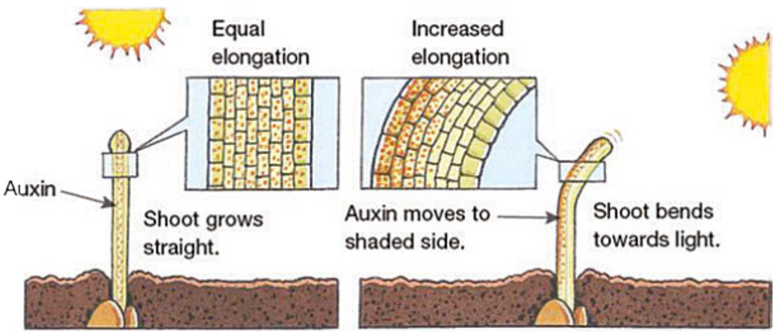
Have you ever watched a plant move? They do, and most gracefully too. If you watch plants over a length of time, or using time-lapse photography, you can see how they move with the Sun and the Moon. These movements may be choreographed by hormones or by their internal biological clocks.

Although they are multicellular organisms, plants do not have a nervous system. However, like animals, they do have hormones. Plant hormones coordinate the way plants grow, develop and respond to their internal and external environments. Plant hormones are mainly produced in the growing tips of roots and shoots, in buds and in developing fruits. Only very small quantities are needed for an effect. The same hormone may produce different responses in different parts of the plant.

Plant hormones are generally divided into five main types:

- **auxins** — promote stem growth, cell expansion and repair. They are transported from the stem tip to the roots controlling the overall shape of the plant (figure 2.50).
- **cytokinins** — involved in cell division, the making of new plant organs and for repair. They are produced in the roots and travel up the stem through the xylem.
- **gibberellins** — play a major role in plant growth and development, for example in signalling fruiting to commence. Works alongside auxins in the plant and are produced in the plastids of a plant cell.
- **abscisic acid** — alerts the plant that it needs water and closes the guard cells to reduce water loss. It travels both up and down a plant cell.
- **ethylene** — affects the ripening and rotting in plants affecting fruit, and the lowering and dropping of leaves. It exists as a gas and is produced in all parts of the plant, diffusing through the plant tissue to the outside.

FIGURE 2.50 Auxins cause plants to grow towards the light.



In some cases, a number of these hormones work together to produce a response. Figure 2.51 shows where these plant hormones are produced and what their effects are.

auxin plant hormone that regulates or modifies the growth of plants such as promoting stem growth, cell expansion and repair

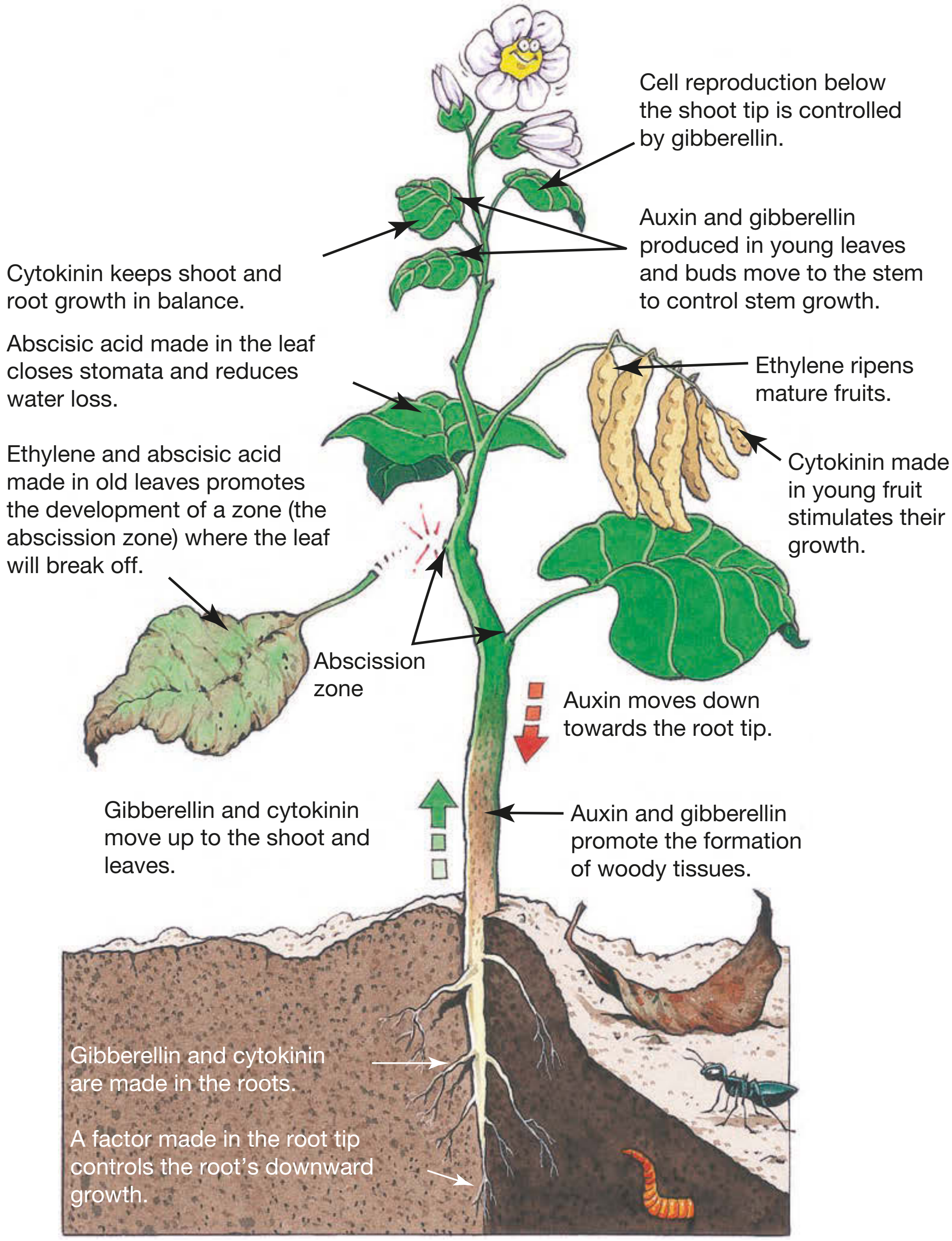
cytokinin hormone that promotes cell division in plants

gibberellin plant hormone that regulates growth, including germination and dormancy

abscisic acid a plant hormone that is involved in the process of development

ethylene gaseous plant hormone involved in the ripening of fruits and the lowering and dropping (abscission) of leaves

FIGURE 2.51 Plant hormones and their roles



DISCUSSION

It takes just one bad apple to spoil the whole bagful. Comment on the validity of this statement with reference to plant hormones.

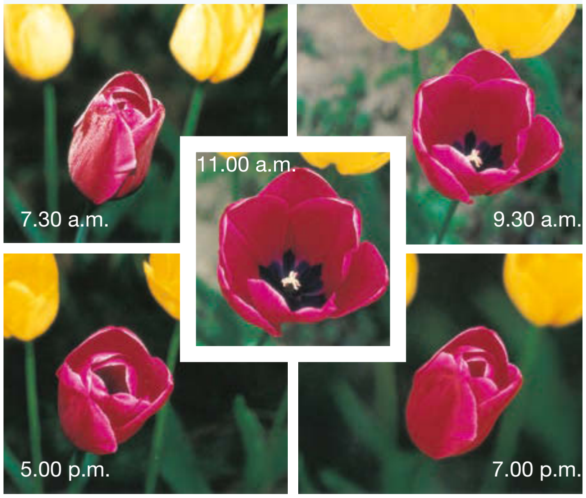
on Resources

Video eLesson Circadian rhythm (eles-2637)

2.7.2 Plant biological clocks

Like us, plants have internal biological clocks and may have different patterns of movement in a 24-hour cycle. The leaves of some plants, for example, may be horizontal during the day and then drop into a 'sleeping' position at night. If you were to place these plants in 24 hours of daylight or darkness, they would continue their 'sleeping' movements because the sleep pattern of these plants is internally controlled. Such a 24-hour cycle is referred to as a **circadian rhythm** or cycle. The opening and closing of flowers is another example of a plant's activities that involves a circadian rhythm. Unlike a plant's movement towards light, these kinds of movements are independent of the direction of the stimulus.

FIGURE 2.52 Getting into circadian rhythm: a flower performs its daily dance.



The timing of flowering of many plants is controlled by the length of uninterrupted darkness.

- Long-day plants flower only when the number of daylight hours is over a certain critical minimum (or when darkness is less than a critical value). Gladioli, cabbage and hibiscus are long-day plants.
- Short-day plants flower only when exposed to daylight that is under a certain maximum number of hours. Daffodils, rice and chrysanthemums are short-day plants.
- Day-neutral plants, such as potatoes and tomatoes, do not depend on day length to flower.

circadian rhythm the 24-hour pattern of behaviour exhibited in animals and plants even if deprived of environmental changes

Different plants flower in response to different day and night lengths.

FIGURE 2.53 a. The poinsettia (*Euphorbia pulcherrima*) is a short-day flower and flowers only when the day length becomes less than 12.5 hours. **b.** The hibiscus (*Hibiscus spp.*) is a long-day plant and flowers only when the day length becomes greater than 12 hours.

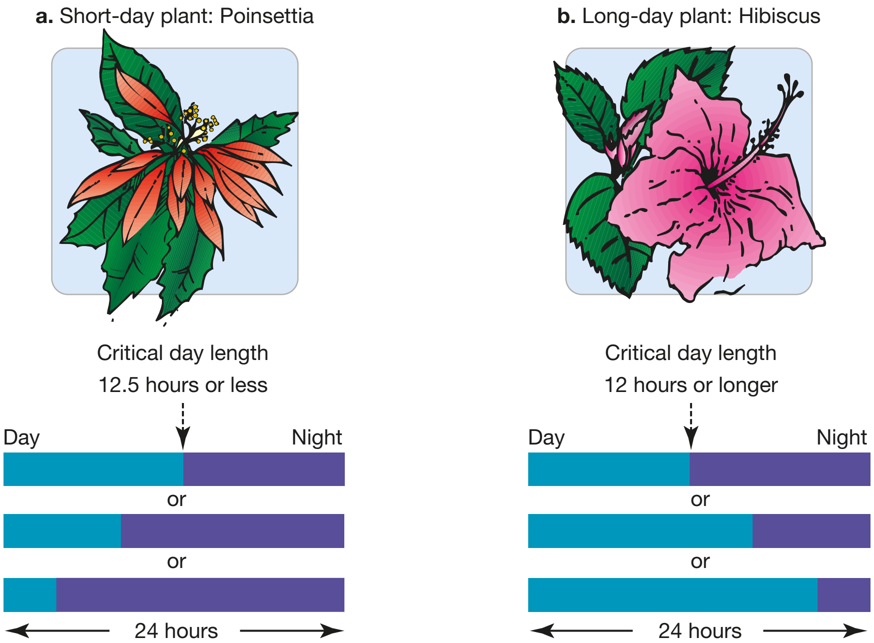


TABLE 2.6 Some examples of short-day, long-day and day-neutral plants

Short-day	Long-day	Day-neutral
Rice (*Oryza sativa*)	Wheat (*Triticum aestivum*)	Corn (*Zea mays*)
Chrysanthemum (*Chrysanthemum spp.*)	Cabbage (*Brassica oleracea*)	Potato (*Solanum tuberosum*)
Poinsettia (*Euphorbia pulcherrima*)	Hibiscus (*Hibiscus syriacus*)	Rhododendron (*Rhododendron* spp.)
Violet (*Viola papilionacea*)	Spinach (*Spinacea oleracea*)	Tomato (*Lycopersicon esculentum*)

DISCUSSION

The amount of daylight changes with the seasons. Why do you think some flowers bloom in spring?

SCIENCE AS A HUMAN ENDEAVOUR: Weed killers

Some selective weed killers that use plant hormones work on particular plants but not others. A type of weed called a dandelion is a common problem in lawns. It produces a familiar yellow flower that turns into a large puffball containing small seeds attached to a feathery umbrella-shaped structure, which helps the plant to disperse its seeds on the wind. Lawns containing the dandelions can be sprayed with selective weed killer without killing the grass. The selective weed killer contains a growth hormone that causes the weeds to grow too quickly. They then use their own resources rapidly and die. The weed killer is absorbed by the weeds in larger quantities than grass.

FIGURE 2.54 Dandelions are actually types of weeds.

EXTENSION: Linking ABA to saving our precious water resources

While virtually all of Australia's horticultural crops are grown using some form of irrigation to supplement rainfall, crops grown under cover are entirely dependent on irrigation. Water for irrigation is becoming an increasingly scarce and expensive commodity. It is therefore vital that we understand the ways that plants use this water so that we can optimise its use and improve economic returns to farmers.

FIGURE 2.55 Dr Loveys investigated the role of the plant hormone abscisic acid in the regulation of water use in grapevines.

Nearly all of the water used by plants passes through pores on the leaf surface called stomata. This causes plants a dilemma. How can they keep their stomata open to obtain carbon dioxide for photosynthesis, while at the same time restrict excessive water loss through them? The answer lies in a surprisingly complex set of control mechanisms.

Right at the heart of the control mechanisms is the plant hormone abscisic acid (ABA). ABA induces stomatal closure and if it is not present plants very quickly die from excessive water loss. Understanding how plants control the amounts of ABA in roots and leaves has therefore been a research priority for scientists over the last few decades.

It has been necessary to develop sensitive methods for measuring ABA because, like most hormones, it is present only at very low concentrations. Using these methods we have been able to show that the ABA concentration in roots responds very quickly to reductions in the amount of water in the soil and that this additional ABA is transported to the leaf to signal stomatal closure.

Dr Loveys said, 'Our scientific team has also used the latest molecular techniques to identify the genes responsible for ABA synthesis and breakdown. Knowledge about the complex ways that the environment interacts with the genetic makeup of the plant to control ABA synthesis and breakdown is allowing us to devise novel irrigation techniques to optimise these mechanisms and improve the efficiency of water use.

'In addition to providing information that is useful to farmers, the research has significantly increased our body of knowledge about how all plants function and, furthermore, has been a lot of fun.'

elog-0635

INVESTIGATION 2.5

The effect of a commercial rooting powder on cutting development

Aim

To investigate the effect of a commercial rooting powder on the development of plant cuttings

Materials

- 10 cuttings (daisies and geraniums work well, but so will lavender and rosemary — they'll just take a little longer)
- 2 × 12-centimetre flowerpots or tubs
- a micro test tube of rooting powder
- potting mix
- 2 labels

Method

1. Trim the lower leaves off all ten cuttings.
2. Fill the flowerpots with soil and label one Control and the other Test.
3. Plant five cuttings in the Control pot and water them.

4. Dip the other five cuttings in the rooting powder, plant them in the Test pot and water them.
5. Place them in a warm position and keep the pots watered equally.

After one week:

6. Dig one cutting up from each pot and compare their root growth.
7. Continue doing this for the next four weeks, adding observations to your table as you go.

Results

1. Construct a table to summarise your data.
2. At one week, two weeks, three weeks and four week: Sketch the features of plants from each pot.

Discussion

1. Identify the pot in which the plants grew the best.
2. Identify which pot contained the plants with the most developed roots.
3. Suggest the plant hormone that you think may be present in the rooting powder.
4. Discuss reasons horticulturalists use rooting powders.
5. Suggest improvements to the design of this experiment.

6. Suggest a hypothesis that could be investigated using similar equipment. (You may use internet research to identify relevant problems to investigate.)
7. Design an investigation to test your hypothesis. Include an explanation for your choice and treatment of variables.

Conclusion

What can you conclude about the effect of commercial rooting powder on cutting development? Remember to refer to both your control and your test.

elog-0637

INVESTIGATION 2.6

Plant responses to hormones

Aim

To investigate the effects of plant hormones

Materials

- 2 pieces of holly
- a small apple
- plasticine
- labels
- 2 small bottles of water
- 2 × 1 L beakers or large jars
- tray or board

Method

1. Select two pieces of holly that are similar (size, age, number of leaves).
2. Set up the experiment as shown in the diagram and leave for 24 hours. Use the plasticine to cover the pouring lip of the beaker. Label each beaker with your name and date.

Results

Observe and record the holly in the two beakers every 24 hours until there are some obvious differences between them. Construct a table to record your observations.

Discussion

1. What differences did you observe in the two beakers over the period of the experiment?
2. What do you think might have caused these differences?
3. Why was it important to select twigs of holly that were similar?
4. What do you think is responsible for the different responses?
5. Construct a hypothesis that relates to this investigation.
6. Identify strengths and limitations of the investigation and suggest ways in which it could be improved.
7. Suggest a research question about plant hormones that could be investigated.
8. Design an investigation to further explore your research question.

Conclusion

Write a clear conclusion for your investigation, explaining the effect of plant hormones.

Resources

eWorkbook Different types of plant hormones (ebwk-5123)

assesson Additional automatically marked question sets

2.7 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. If plants do not have a nervous system, what coordinates their life cycle?
2. Complete the following table.

TABLE Location and role of plant hormones

Plant hormone	Location of production	Role in plant
Auxin		
		Cell division
	Plastids in plant cell	
Abscisic acid		
		Ripening and rotting

3. Which two factors are thought to control the timing of flowering?

Apply and analyse

4. What is a circadian rhythm? Give an example.
5. Describe how hormones allow a plant to grow towards light.
6. Explain and provide examples of:
   a. long-day plants
   b. short-day plants
   c. day-neutral plants.

Evaluate and create

7. SIS By knowing the effects of plant hormones, horticulturists are able to control the timing of the flowering of plants and the ripening of fruits. Why do you think they do this?
8. Why would gardeners put bulbs of some kinds of plants, such as tulips, in a refrigerator for some weeks before planting?
9. SIS Bananas are often picked green before they are shipped. These green bananas are often artificially ripened. Explain the likely way they may be artificially ripened and why this artificial ripening is used as a preference for picking already ripened bananas.
10. SIS Find out more about Australian research that involves plant hormones. In your report, identify the hormone and its function and the reason for the research.

Fully worked solutions and sample responses are available in your digital formats.

2.8 Emotions and the limbic system

LEARNING INTENTION

At the end of this subtopic you will be able to explain how the limbic system of the brain influences the emotions humans feel.

2.8.1 Your emotional brain

Imagine a situation in which you have felt threatened. How did you feel? How did you react? Did you want to run, or did you want to stay and fight?

Your emotions enable you to react to situations. They are caused by the effects of chemicals binding to receptor sites on your cells, and they influence your behaviour. Our ancestors relied on their emotions to survive. Sometimes there is no time to think about how to react to a situation. This is when your emotional brain can get into the driver's seat and take control. The six basic emotions that humans experience are happiness, sadness, fear, disgust, anger and surprise.

Your 'emotional brain' or **limbic system** is made up of a collection of structures within your brain. The limbic system is involved in memory, controlling emotions, decision making, motivation and learning. These include parts of your thalamus, hypothalamus, hippocampus and **amygdala**.

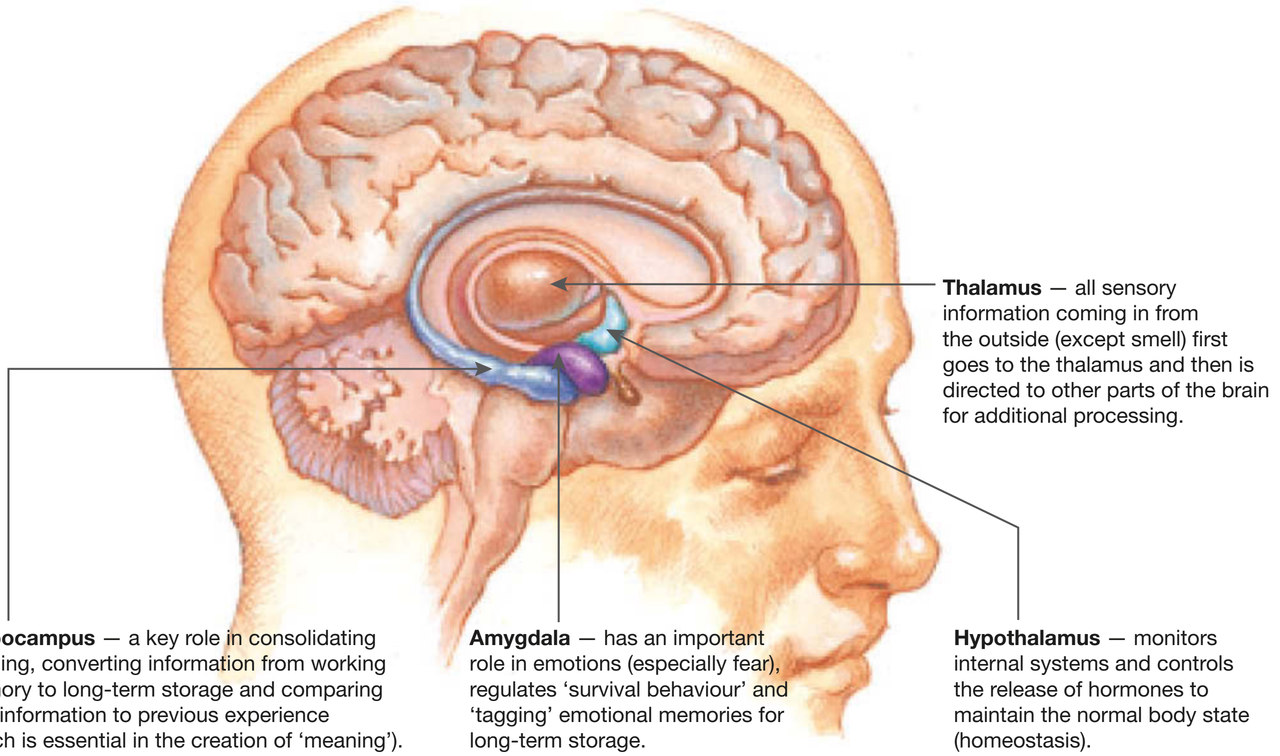
limbic system a collection of structures within your brain involved in memory, controlling emotions, decision making, motivation and learning

amygdala emotional centre of the brain, which processes primal feelings such as fear and rage.

ewbk-5125

eles-2638

FIGURE 2.56 The limbic system in your brain



2.8.2 Fight-or-flight response

Feeling angry? Is your heart racing; are your hands cold; do you have a sick feeling in your stomach? Anger can be one of our most primitive emotions. It is certainly a powerful one. Uncontrolled anger can lead to physical fights, arguments and self-harm. However, controlled anger can be a very useful emotion that can help motivate you to make positive changes.

When you feel angry, your hypothalamus responds by sending messages to your pituitary gland to instruct your **adrenal glands** to release **adrenaline** (also known as epinephrine). This hormone acts to:

- increase your heart rate
- dilate your pupils
- constrict skin blood vessels
- shut down digestion.

This helps you to see any threats better and provides your muscles with more glucose and oxygen, just in case you need to face the danger and *fight*, or take *flight* and escape it by running away.

adrenal glands a pair of glands situated near the kidneys that release adrenaline and other stress hormones

adrenaline a hormone secreted in response to stressful stimuli, which readies your body for the fight-or-flight response

mirror neurons group of neurons that activate when you perform an action and when you see or hear others performing the same action

empathy the capacity to recognise and to some extent share feelings that are being experienced by other people

Recognising the threat

Your fight-or-flight response actually originates in your amygdala. It is this tiny part of your limbic system (about the size of your thumbnail) that decides the emotional value of what is happening. It may sense a particular facial expression or tone as being threatening, or it may detect an event that was previously 'tagged' as being a negative experience.

Long-term anger or stress

Staying angry, or long periods of stress, can damage another part of your limbic system called your hippocampus. If the stress or anger lasts more than a few minutes, your adrenal glands also release cortisol. Sustained high levels of this hormone can lead to the death of hippocampus neurons, which may result in diminished learning, spatial recall and memory.

Recognising a false alarm

Your prefrontal cortex or thinking brain is also involved in assessing a threat and placing it in context. If your thinking brain considers it to be a *false alarm*, it sends a message to your hypothalamus to trigger actions to calm things down; it does this by sending out messages to decrease your stress hormone levels and their effects.

ACTIVITY: Feeling angry?

What if no-one ever got angry? Would this be a good thing? Imagine what the world would be like. Construct a PMI chart about your imagined world.

2.8.3 How neurons and neurotransmitters control your mood

Empathy

Feel upset, or feel upset for someone else? **Mirror neurons** are a group of neurons that activate when you perform an action and when you see or hear others performing the same action. Research is suggesting that these neurons are important in being able to feel **empathy** towards other people. If this theory is further supported, how could this connection increase the chances of the survival of our species?

Mood chemistry

Neurotransmitters are chemicals involved in passing messages between your nerve cells (refer back to 2.3.2). Within your brain there are many neurotransmitters that influence how you feel and react; **serotonin**, **noradrenaline** (also known as norepinephrine) and **dopamine** are three examples. Imbalances of these neurotransmitters can contribute to a variety of mental illnesses.

- Serotonin acts like the brakes on your emotions. It can produce a calming effect and is important for maintaining a good mood and feelings of contentment. It also plays a role in regulating memory, appetite and body temperature. Low levels of serotonin can produce insomnia, depression and aggressive behaviour and are also associated with obsessive–compulsive and eating disorders.
- Noradrenaline can act like the accelerator. It can promote alertness, better focus and concentration. Your brain also needs this chemical to form new memories and to transfer them to your long-term storage.
- Dopamine is important for healthy assertiveness and autonomic nervous system function. Dopamine levels can be depleted by stress or poor sleep. Too much alcohol, caffeine and sugar may also lead to reduced dopamine activity in your brain. People with Parkinson's disease have a diminished ability to synthesise dopamine.

serotonin a common neurotransmitter involved in producing states of relaxation and regulating sleep and moods

noradrenaline also called norepinephrine; common neurotransmitter involved in arousal states

dopamine a neurotransmitter involved in producing positive moods and feelings.

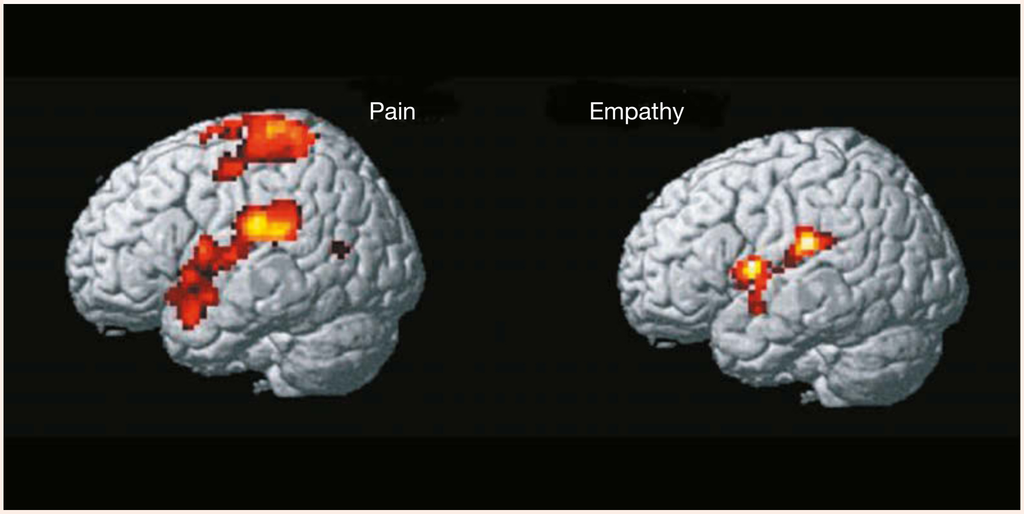
DISCUSSION

- Do our hormones determine who we are and what we do, or can we have some conscious control over this?
- Suggest how mirror neurons may increase the survival of our species.

SCIENCE AS A HUMAN ENDEAVOUR: Brain studies using MRI

Early brain research used dead or diseased brains. Advancements in scientific applications of technology have enabled researchers to examine living brains. One such technology is magnetic resonance imaging (MRI), which allows scientists to actually see which parts of the brain are active when various tasks are performed; these parts 'light up' with different colours to show brain activity.

FIGURE 2.57 MRI images show the responses of a person in pain (left) and a person watching someone in pain, producing empathy (right).



EXTENSION: Emotions and learning

Are emotions gatekeepers to your intellect? Are emotions important to your learning too? If emotions are important to your learning, are some emotions better than others? Can some emotions actually interfere with your learning?

If this is the case your learning can be enriched if you are in a safe, caring and inviting climate for learning. If you were to describe your ideal learning environment, what would it look like, feel like and sound like?

Feeling safe and taking risks

In a safe and caring environment, learning by trial and error is very effective. This means you feel comfortable to ask questions and feel safe enough to risk making mistakes or getting something wrong. When the learner experiences stress or feels threatened, survival instincts can take over. Chemicals are released that place their body in a heightened alert phase, to help prepare them for a possible dangerous situation. If a learner is in this stressed state it is difficult to use higher-order thinking, and it can be difficult to learn effectively.

FIGURE 2.58 Survival instincts often take over in high risk situations.

While your hippocampus has an important role in forming long-lasting memories, your amygdala can act as a memory filter, labelling information to be remembered by tying it to events or emotions that are experienced at the time.

When you are experiencing a time of stress, your survival instincts can take over. You produce chemicals that place your body in a heightened alert phase, to help prepare you for a possible dangerous situation. When you are in a stressed state it is difficult to use your higher-order thinking and you may find it difficult to learn effectively.

Not all challenges and stresses are bad for learning. When the brain is faced with a challenging, intricate and complex problem, all of its parts can be involved and attention, meaning and relevance for learning can result.

on Resources

eWorkbook The body continuum (ewbk-5127)

assesson Additional automatically marked question sets

2.8 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Name the six basic human emotions.
2. Match the term with the most appropriate description in the table provided.

Term	Description
a. Amygdala	A. Collection of structures within your brain involved in memory, controlling emotions, decision-making, motivation and learning
b. Hippocampus	B. Organ involved in sensory memory and 'attention'
c. Limbic system	C. Involved in converting information from working memory to long-term storage and helping to make 'meaning' of new information by comparing it to previous experience
d. Thalamus	D. Plays a key role in emotions by regulating 'survival behaviour' and 'tagging' emotional memories for long-term storage

3. Describe the function of dopamine.
4. Outline the role of serotonin and discuss why this neurotransmitter is important.

Apply and analyse

5. Describe the relationship between the pituitary gland, the adrenal glands and adrenaline.
6. Outline the relationship between prolonged stress or anger, cortisol and learning.
7. Describe how your hypothalamus can be involved in controlling stress.
8. Explain how the release of adrenaline can increase your chances of survival.
9. a. Identify three neurotransmitters in your brain that can influence how you feel and react.
   b. Describe the effects that each of these neurotransmitters can have on your behaviour.
10. Adrenaline is referred to as the fight-or-flight hormone.
    a. Why is it known as this?
    b. Suggest some advantages and disadvantages of the effects of adrenaline in modern-day living.

Evaluate and create

11. SIS Can fears or phobias be unlearned? Find out more about research involving chemicals such as glutamate to achieve this.
12. Find out about the connections between brain neurotransmitters, behaviour and one of following medications: Prozac, Zoloft, Topamax, Provigil and Abilify.
13. Some convicted murderers may have killed in a 'fit of rage'. Find out if there are any documented links between committing murder and frontal lobe activity in the brain.
14. Have you seen a young child throw a tantrum? This is a case of not being able to control emotions. Although the child's amygdala is fully mature, the necessary links with the cortex are not yet fully developed. Explain the link between different parts of the brain and their effects on the behaviour in small children.

Fully worked solutions and sample responses are available in your digital formats.

2.9 Memory

LEARNING INTENTION

At the end of this subtopic you will be able to explain how the memories are formed in the brain and strategies we can use to improve our memories.

2.9.1 Making memories

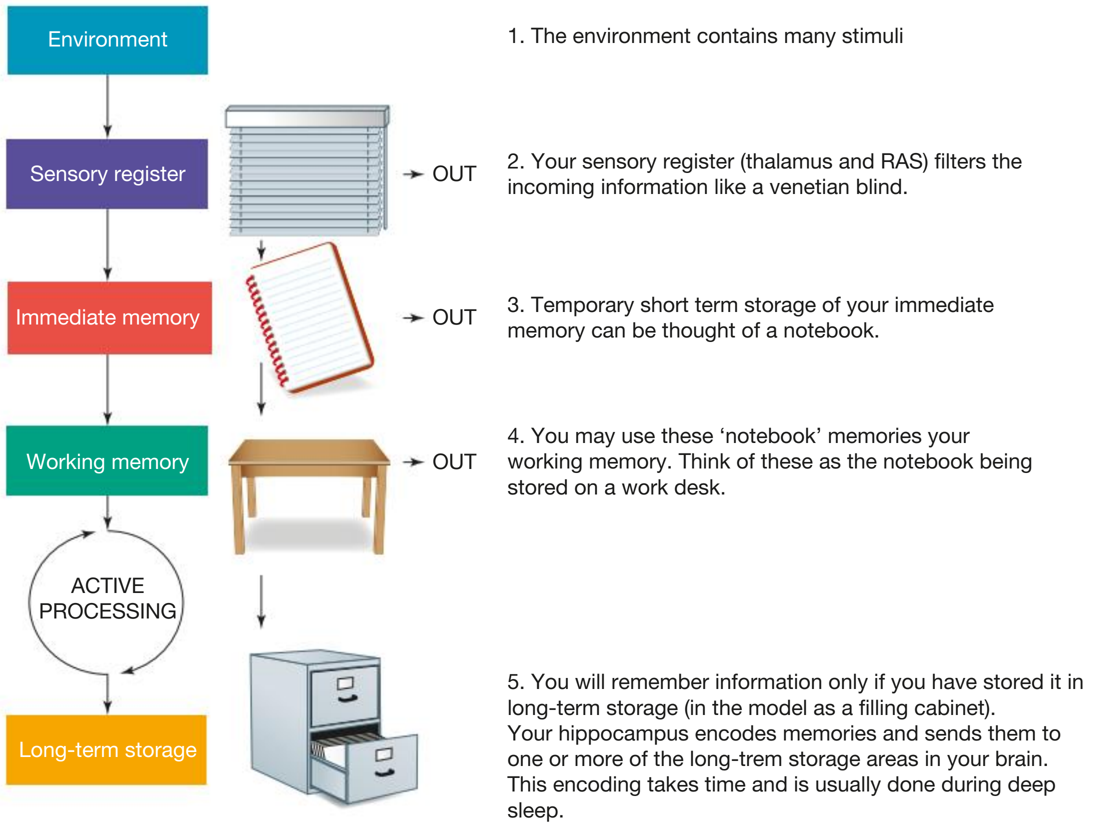
If a friend gave you her phone number, how long could you remember it without writing it down? While learning is about gaining new knowledge, memory is about retaining and then retrieving that learned information. That is, for us to remember something, we have to be able to record the experience and store it in an appropriate part of the brain. If we are unable to retrieve or pull out that information, we have forgotten it.

SCIENCE INQUIRY: Using a model to understand memory

Scientists construct models to communicate ideas. Models can be concrete (for example, a plastic model of the brain) or symbolic (for example, a map or diagram). Models provide the opportunity for learners to bring previous knowledge into their working memory. This helps learners to attach meaning to, and make sense of, their new learning.

A model can be used to represent various stages in how information is processed by your brain. Figure 2.59 is a simplified version of an information-processing model. While this model has many limitations, it provides a framework that can be used to help you attach previous knowledge to new learning about the stages of memory.

FIGURE 2.59 Model of the various stages of how information is processed in your brain. Memories that are immediate or working are lost if they are not moved to long-term memory.



2.9.2 Making memories

You use your senses (for example, sight and hearing) to detect various stimuli in your environment. Incoming information is filtered, on the basis of its importance to you, through a system called the **sensory register** (shown in figure 2.59 as venetian blinds). The sensory register involves:

- your thalamus (a part of the limbic system of your brain)
- reticular activating system (RAS) within your brain stem.

sensory register part of the information processing model of the brain that involves filtering incoming information

Immediate memory

Information that has made it past your thalamus moves to your immediate memory where a decision is made about what to do with it (shown as a notebook in figure 2.59). Your past experience helps to determine its importance.

An example of the length of time information will stay in this type of memory is when you temporarily remember a phone number and ring it. After this time the information may be lost or, if considered important enough, moved to your working memory.

Working memory

It is within your working memory that information generally captures your focus and demands attention (shown as a work desk in figure 2.59). There is a limited capacity (amount of information dealt with) and time limit for this type of memory. This can often be associated as short-term memory

Research suggests that this capacity changes with age. Between the ages of 5 and 14 years there is a range of about 3–5 'chunks' that can be dealt with at one time; after this age it increases to about 5–7 chunks. This limited capacity is one of the reasons why you need to memorise songs, poems or other information in stages. By memorising a few lines at a time and repeating them (or rehearsing them) you are able to increase the number of items in your working memory. This is an example of chunking.

Studies have suggested that the time limit in working memory is about 10–20 minutes. This is often the amount of time you can spend on one activity. However, this time, can be influenced by interest and motivation. Both of these can have emotional elements and also involve a special part of your brain called the amygdala.

Long-term memory

You will remember information only if you have stored it in long-term storage (shown in figure 2.59 as a filing cabinet). It is the job of your hippocampus to encode it and send it to one or more of the long-term storage areas in your brain. This encoding takes time and is usually done during deep sleep.

Memories are not stored as a whole or in one place. When you retrieve and reconstruct memories, storage areas distributed throughout your brain are activated. It is currently thought that memories exist as patterns of connections at the synapses between the brain's neurons. To store a particular memory, nerve signals travel along a specific pathway through certain synapses. Each time this memory is remembered, nerve signals are reactivated to again travel along this pathway.

Your long-term memory relates to the dynamic process of sorting and retrieving the information.

ACTIVITY: Short-term memory

Get a pencil and paper and then concentrate on the number below for 7 seconds. After 7 seconds, look away and write the number down. Did you get it right? Compare with others in your class.

5167340

Now repeat the procedure again with the number below. Did you get it right? Compare with others in your class. Did you get the same results for each number? Discuss your results with your team. Suggest a reason for any differences between results.

3847918362

2.9.3 Remember to learn

Your past experiences influence new learning. What you already know acts as a filter to help you focus on things that have meaning and ignore those that don't. Your self-concept (how you see yourself in the world) is also shaped by your past experiences. It is your self-concept that often determines how much attention you will give to new information.

You can transfer things from your short-term memory into your long-term memory by rehearsing information (practising) and applying meaning to it. The two key questions asked in the decision of whether to move information into long-term memory are:

- does it make sense?
- does it have meaning?

I don't understand! This is the type of comment made when a learner is having trouble making sense of new learning. Determining whether new information 'makes sense' is related to whether the new information fits in with what you already know.

Why do I have to know this? Whether the new information 'has meaning' relates to whether it is relevant to you and whether you consider that the purpose of remembering it is worthwhile. You can improve the chance that you remember something by making connections between the new learning and your previous knowledge.

TABLE 2.7 If both sense and meaning are present, there is a very high chance that the information will be sent to long-term storage.

		Is sense present?	
		No	Yes
Is meaning present?	Yes	Moderate to high	Very high
	No	Very low	Moderate to high

CASE STUDY: Tips for learning and remembering

There are keys that you can use to unlock your memory doors. Seven of these are primacy, recency, repetition, standing out, association, chunking and visuals.

primacy remembering the first time that you do something, or the beginning of something

recency remembering the last time that you do something, or the end of something

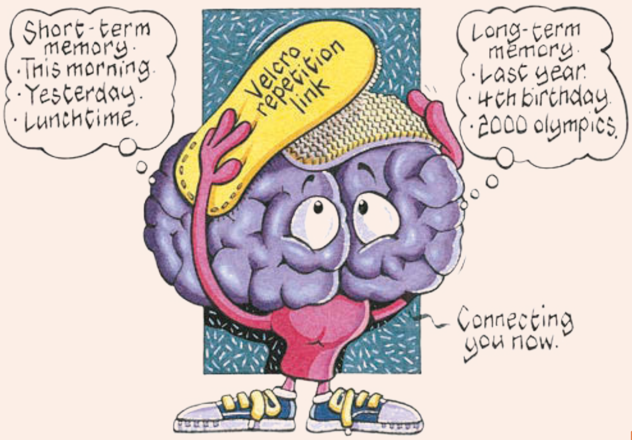
Primacy and recency

When you read a book or see a movie you will usually remember the beginning and the ending. **Primacy** is about recalling and remembering the first time that you do something. **Recency** is the opposite. It is remembering the last time or the ending.

Repetition

Repetition, or regularly reviewing information, is needed to reactivate your stored memory and prevent it from being buried under layers of other information. Research suggests that you can achieve about 90 per cent recall if you review content within 24 hours. This drops to 30 per cent if you review after 72 hours (3 days). Repetition can be achieved visually, by reading, playing games with the new information, highlighting or using visual thinking tools.

FIGURE 2.60 Repetition is important to help move content from short-term to long-term memory



Standing out

Think about a lesson that you remember well. What made it more memorable than other lessons? Was it fun? Was there something different or new about the experience? Did you use mnemonics or analogies? A mnemonic is a technique that helps you remember something. This may involve telling a tale (using key terms within a story), linking (linking terms and images) or using acronyms (using the first letters of words; for example, SPEWS). Some of these ideas are very effective because they overlap with other memory keys. All of these things can help content stand out and make it easier for you to remember it.

Association

If new knowledge is linked to previous knowledge your recall is greatly enhanced. This is called learning by association. It helps you to anchor the information in time and space. Using real-life examples or metaphors can assist in this, as can the use of smell, music and colour.

Chunking

You don't have to learn everything all at once. The short-term memory of teenagers can usually contain only five (plus or minus two) bits of information at once. By organising information into small chunks, it is easier to remember it.

Visuals

Reading text in colour can help you to use both sides of your brain. The same can be said for a dramatic acting out; for example, performing the story of how blood flows through your body.

ACTIVITY: Mnemonics

Create a mnemonic to help you remember the seven tips of learning and remembering.

2.9.4 Forming and blocking memories

Memory formation

A key neurotransmitter involved in learning and memory formation is **acetylcholine**. This neurotransmitter is released in the brain during learning. Acetylcholine is involved in the strengthening of connections between neurons in the brain and hence in the formation of new memories. Consequently, drugs that boost the amount of acetylcholine release are used as a treatment for diseases such as Alzheimer's, that impair cognition.

acetylcholine produced in vesicles in a neuron, this neurotransmitter is released on the arrival of a nervous impulse to travel across the synapse (gap between neurons) to stimulate an impulse in another neuron

SCIENCE AS A HUMAN ENDEAVOUR: Memory blockers

Scientists are working on drugs to improve or even erase memory. Drugs that can enhance learning are being sought as an easy way to do well in tests and exams. However, there are disadvantages and advantages to drugs designed to block memories.

Current research includes studies on drugs that specifically block or erase problem memories at the molecular level. While this can be a great advantage to those who suffer post-traumatic stress disorder (PTSD), there are concerns that other memories could also be erased.

Researchers are exploring the possibility of using chemicals called beta-blockers, cortisol and hydrocortisone to alter our memory processes. Beta-blockers can bind to the receptors on the cell surface that would usually bind to adrenaline and noradrenaline. By blocking these hormones, beta-blockers may stop the hormones' stressful effects and prevent deep memory formation.

While all this research is exciting and innovative, what are the ethical considerations? Who controls which memories are to be erased and when? What do bad memories have to do with our consciences and our perceptions of right and wrong? Will there be global rules and regulations? If so, who will write them and make sure that they are maintained?

Stressful memories down deep

Your hippocampus and amygdala are also involved in emotional responses to an experience or memory. When your sense organs pick up a stimulus it goes to your thalamus and is then dispatched to your amygdala to assess its emotional quality. If it is recognised as potentially threatening, it triggers your body to release adrenaline and noradrenaline to set you up for fight or flight. The hippocampus then processes the memory and imprints it deeper than it would other memories. This will allow you to be primed quickly for action if it occurs again.

In this way, memories of traumatic or highly emotional events are burned into your brain more deeply and are remembered for longer. While in evolutionary terms this may have increased our chances of survival, traumatic events can result in PTSD.

on Resources

Weblink Memory, attention and distraction

assesson Additional automatically marked question sets

2.9 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Describe the process of chunking and state what part of memory this is associated with.
2. How can you transfer short-term memory into long-term memory?
3. Outline the importance of acetylcholine in the formation of memory.
4. Name the part of the brain that transfers information from short-term memory to long-term memory.

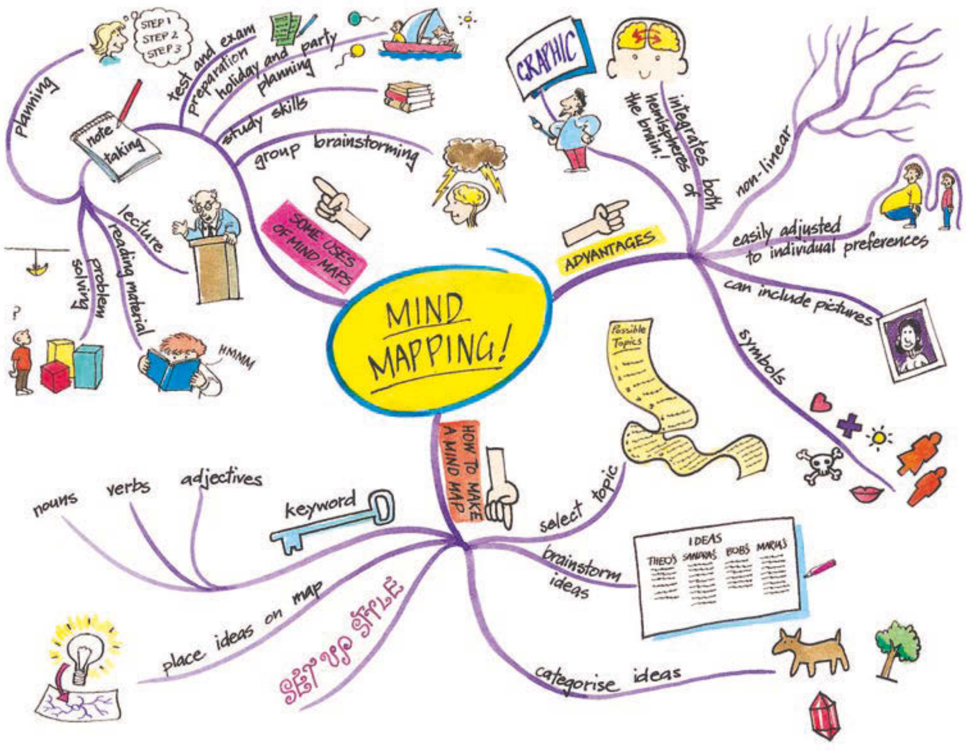
Apply and analyse

5. List the different memory systems and write a brief description of each in your own words.
6. The colour red is directly stored in your long-term memory. List examples of vehicles, signs and symbols that have applied this knowledge. Suggest why your brain processes the colour red in this way.
7. Suggest the advantage of traumatic or emotionally charged events being remembered more deeply.

Evaluate and create

8. Describe each of the strategies used to help with memory, providing an example for each.

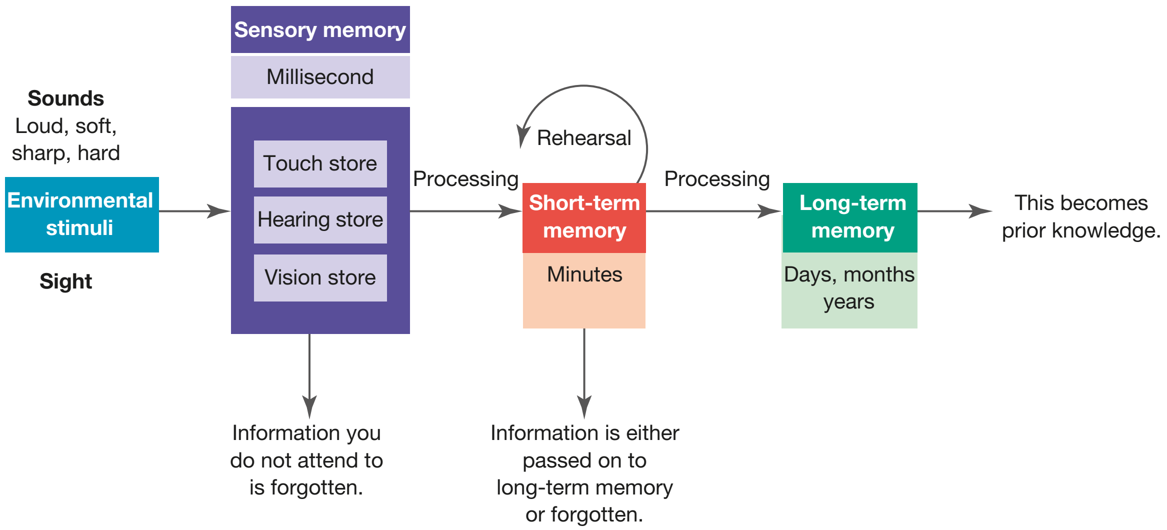
9. Mind maps are excellent tools to help you with your memory. An example of a mind map is shown.



Create a mind map to summarise the different memory systems (such as long-term memory).

10. SIS Carefully observe the information-processing memory model shown.

a. Identify strengths and limitations of this model in its communication of how memories are formed.
b. Suggest improvements to this model.
c. Identify the similarities and differences between this model and figure 2.59.
d. Which model best helps you understand the concepts related to memory? Why?
e. Explain why scientists used models to communicate their understanding of our brain's functions.



Fully worked solutions and sample responses are available in your digital formats.

2.10 Sleep

LEARNING INTENTION

At the end of this subtopic you will be able to describe how the brain regulates sleep and what happens in the brain before and during sleep.

2.10.1 How your brain regulates sleep

Are you a night owl or an early bird? Do you get sleepy during the day or find it hard to wake up in the mornings?

The reticular formation is a network of fibres and cell bodies is located in the central core of your brain stem (medulla oblongata) and extends through other areas of your brain. It can be considered a network of neurons that opens and closes to increase or decrease the amount of information that flows into and out of your brain. It helps regulate your alertness (from being fully awake or deeply asleep), motivation, movement and some of your reflexes.

Circadian rhythm

It is not only plants that have a circadian cycle (refer back to 2.7.2). Animals, including humans, also have their own biological clocks. Your circadian rhythm is the regular pattern of mental and physical changes that happen to you throughout a 24-hour time period. This clock is really a pair of pin-sized structures made up of about 20 000 neurons called your **suprachiasmatic nucleus (SCN)**, which is located in your hypothalamus, near where your optic nerves cross.

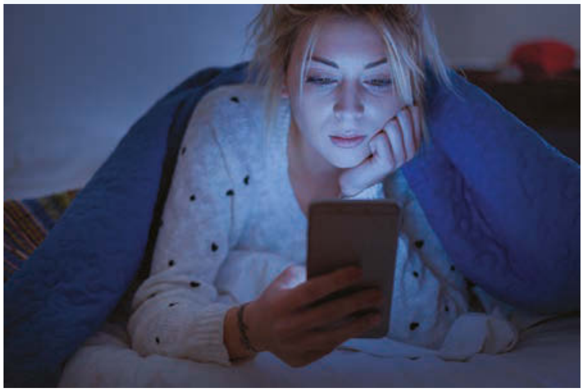
suprachiasmatic nucleus (SCN) the biological clock, located in the hypothalamus near where the optic nerves cross

melatonin hormone produced by the pineal gland that is involved in sleepiness

Light and hormones

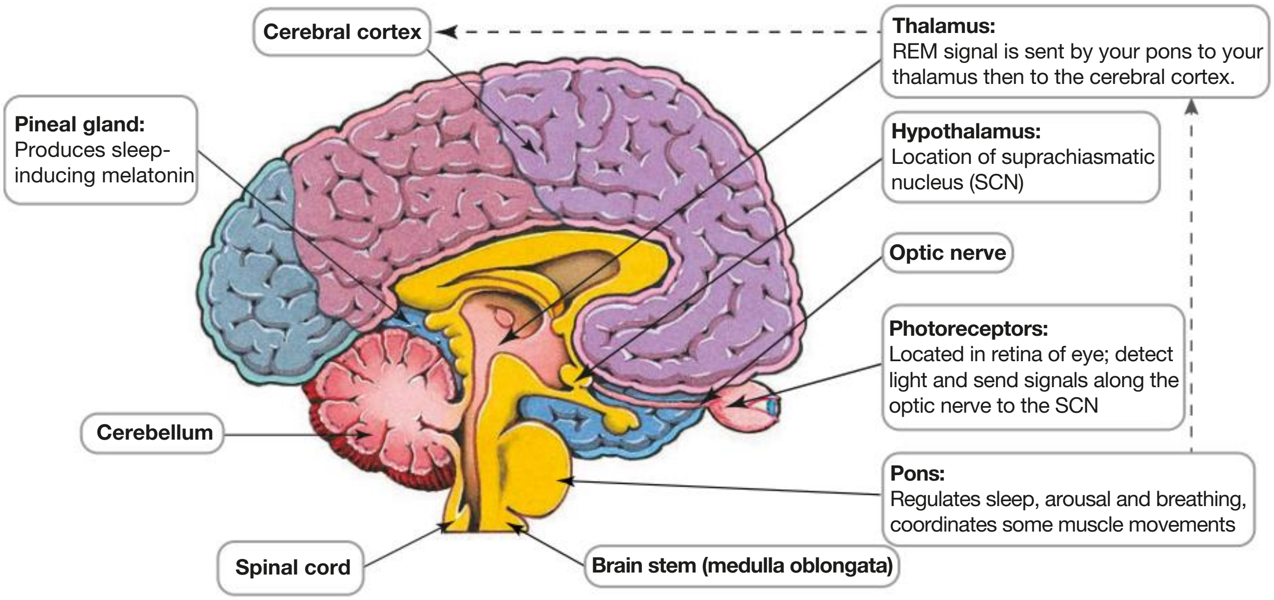
Why do you often get drowsy when it is dark and wake up when it is light? The answer lies in your nervous system and levels of chemicals in your brain. Photoreceptors in the retina of your eye detect light and create signals that travel along your optic nerve to your SCN. Your SCN then sends signals to a number of different parts of your brain.

FIGURE 2.61 The blue light emitted by digital devices prevents the production of melatonin.



In the evening, the signal that light is decreasing travels from your SCN to your pineal gland, which then produces a hormone called **melatonin**. Increased levels of melatonin in the evening tell your body that it's time to sleep and you begin to feel drowsy. During adolescence, these levels peak later in the day, which may explain why you get tired later at night and want to sleep in the next morning. However, the blue light emitted by mobile phone screens, tablets and televisions slow or prevent the production of melatonin, making it harder to fall asleep and stay asleep.

FIGURE 2.62 How the different components in your brain are involved in sleep



Neurotransmitters

Neurotransmitters can also control whether you are asleep or awake by acting on particular groups of neurons in your brain. The neurotransmitters serotonin and norepinephrine keep some parts of your brain active while you are awake. During sleep, the production of these neurotransmitters is switched off. As these chemicals are involved in logical and consequential thinking, your judgement of time and location can become distorted.

FIGURE 2.63 Some examples of ways in which you can improve the quality of your sleep

Some foods and medicines can change the balance of your neurotransmitters and affect how alert or drowsy you are and also how well you sleep. Drinks or foods that contain caffeine stimulate some parts of your brain and can cause insomnia (inability to sleep).

Neurons involved in controlling sleep also interact closely with your immune system. Infectious diseases like the flu can make you feel sleepy. This may be because of the powerful sleep-inducing chemicals of our immune system called **cytokines**. Sleep may also help you to conserve energy and other resources that the immune system may need.

cytokines signalling molecules that regulate the function between cells of the immune system

2.10.2 Sleep cycles

During the night, your body experiences sleep cycles lasting 90–110 minutes, with periods of REM (rapid eye movement) and non-REM sleep. You might have three to five sleep cycles each night.

Stages of non-REM sleep

There are four stages of non-REM sleep, and about 75 per cent of your night's sleep is spent in non-REM sleep.

- Stage 1 — lasts for about 5 per cent of your sleep and is a transition period from wakefulness to sleep. During this stage, your muscles may contract and you may feel 'jumps' or 'twinges' in your legs.
- Stage 2 — lasts for about 45 per cent of an average night's sleep. In this stage, your brainwaves become larger and eye movements cease.
- Stages 3 and 4 — (stage 3 accounts for about 12 per cent and stage 4 accounts for about 13 per cent of non-REM sleep) your brain will show delta wave activity. You will be in a deep sleep and be difficult to arouse.

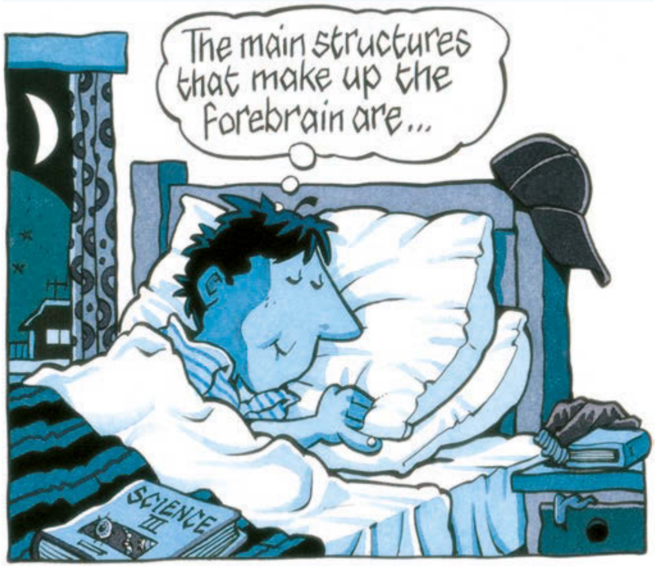
REM sleep

Your REM sleep is your dream time, and usually makes up about 20–25 per cent of the night's sleep. In REM sleep, your breathing becomes more rapid, irregular and shallow and your eyes flick in different directions. Your first REM sleep each night lasts about 70–90 minutes. If you are woken during REM sleep, you can often describe your dreams.

REM sleep is triggered by the pons in your brain. Your pons also shut off neurons in your spinal cord to temporarily paralyse your limbs so that you don't act out your dreams. The REM sleep signal is sent by your pons to your thalamus, then to the cerebral cortex.

Heavy smokers may have reduced amounts of REM sleep and sleep lightly. Although alcohol can help you to fall into a light sleep, it also reduces REM and deep restorative stages of sleep.

FIGURE 2.64 REM sleep is triggered by a structure in the brain called the pons.



Sleep is important because during REM sleep the regions of your brain used in learning are stimulated. It is thought that during sleep your brain consolidates and practises what has been learned during the day. This suggests that learning continues to take place while you sleep.

on Resources

Video eLesson During REM the eyes flick in different directions (eles-2640)

2.10.3 Catching brain waves

Your brain emits waves of electrical impulses at different frequencies when it is engaged in different activities. These frequencies are measured in cycles per second (cps) or hertz (Hz). Technologies such as an **electroencephalogram (EEG)** can be used to measure the patterns of this electrical activity.

electroencephalogram (EEG) a device that detects and records the electrical activity of the brain

Beta (β) waves (13–30 Hz) are the fastest waves with the shortest wavelength. When your brain is emitting beta waves you are using many of your senses and are strongly engaged. An example of this may be if you were involved in an active conversation at a party or playing sport. This type of brainwave is associated with short-term memory, alertness and concentration and is in very high levels if you are anxious about something.

When your brain is emitting **alpha (α) waves** (8–12 Hz), it is likely that you are calm and relaxed, but still aware of your environment. If you are involved in solving a problem, reflecting on an experience or creatively visualising something, you may be emitting this type of wave. When your brain is in this state you may be processing information and activating your long-term memory.

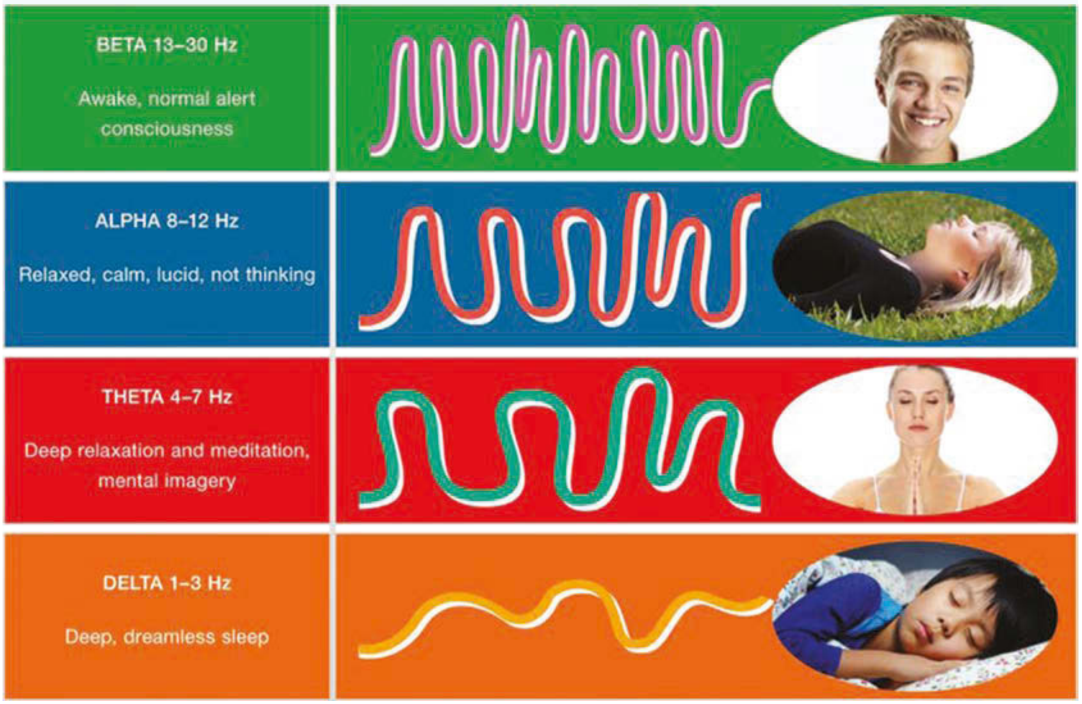
When you are in a deep dreamless sleep, your brain will be emitting **delta (δ) waves**.

beta (β) waves waves of electrical impulses emitted by your brain at a frequency of 13–30 Hz associated with being strongly engaged and using many of your senses, and perhaps with anxiety

alpha (α) waves waves of electrical impulses emitted by your brain at a frequency of 8–12 Hz associated with being calm, relaxed but aware of your environment

delta (δ) waves waves of electrical impulses emitted by your brain at a frequency of 1–3 Hz associated with being in a deep, dreamless sleep

FIGURE 2.65 Your brain emits electrical impulses at different frequencies when it is engaged in different activities.



DISCUSSION

An electroencephalograph (EEG) can be used to measure the overall patterns of electrical activity of your brain. Using figure 2.65, what types of wave activity would you predict to have when you are asleep? Do you think your brain waves are different when you are awake and relaxed compared to when you are awake and alert?

on Resources

assesson Additional automatically marked question sets

2.10 Exercise

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

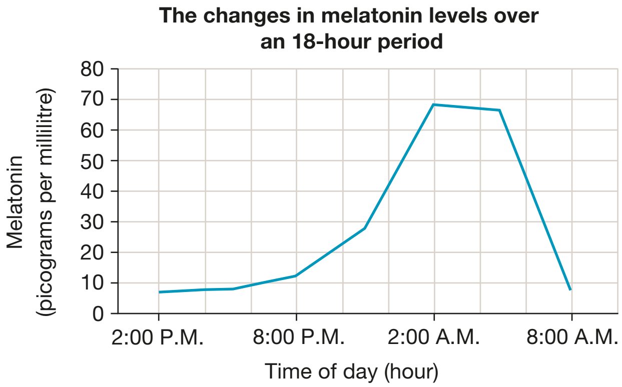
1. What is a circadian rhythm?
2. Where is your suprachiasmatic nucleus (SCN) located and what does it do?
3. How is light involved in whether or not you are sleepy?
4. What effect do increased levels of melatonin have on your body?

Apply and analyse

5. What effect can the switching off of serotonin and norepinephrine have on you?
6. Do you spend more time in REM or non-REM sleep? In which one are you likely to dream?
7. If you don't get enough sleep, you may be drowsy and unable to concentrate. Severe sleep deprivation may result in hallucinations and mood swings. What are some other consequences of sleep deprivation?
8. Which types of brainwaves are seen in deep, dreamless sleep?
9. Suggest why infectious diseases like the flu might make you feel sleepy.

Evaluate and create

10. SIS Consider the effect of light pollution in your bedroom. Describe an experiment you may conduct to test this.
11. Investigate and report on one of the following sleep conditions: sleep apnoea, narcolepsy, restless leg syndrome, talking in your sleep, sleepwalking, night terrors.
12. SIS
    a. Describe the pattern observed in the melatonin levels in the graph shown.
    b. Suggest an interpretation of the observed pattern.
    c. Use other resources to find out more about melatonin and its effects on your body.
    d. Suggest a link between light, melatonin and the body's resulting responses.
    e. Suggest how melatonin levels may affect your learning.
    f. Research seasonal affective disorder (SAD) and determine a possible link to melatonin levels.



Fully worked solutions and sample responses are available in your digital formats.

2.11 The teen brain

LEARNING INTENTION

At the end of this subtopic you will be able to describe the changes that occur in the brain during adolescence.

As explored in earlier subtopics, there are many regions of the brain with a variety of different and vital functions. Over time your brain develops and changes. These changes are occurring for you right now in adolescence and will continue to do so as you age.

CASE STUDY: The teen brain

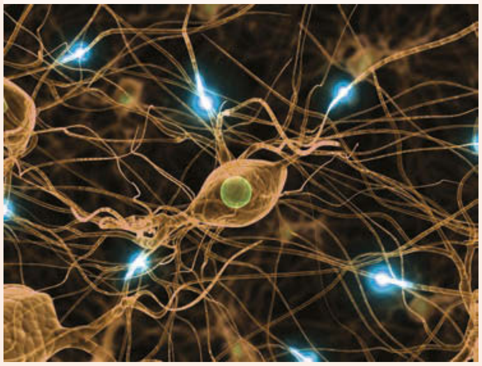
Growth spurts and pruning

Did you know that you had more neurons in your brain before you were born? Most of your brain development occurs in two stages: growth spurts and pruning. Throughout the first months of your life, your brain grew rapidly, producing millions of brain cells. A few months before you were born, there was dramatic pruning of your brain cells to remove unnecessary cells.

Between the ages of about 6 and 11, neurons grow bushier and make dozens of connections (synapses) to other neurons, creating new pathways for nerve signals. This process peaks at around ages 11–12.

Use it or lose it! Synapses are the connections between the neurons where the message is passed from one neuron to the next. The synapses that carry the most messages get stronger and those that are not used much grow weaker.

FIGURE 2.66 There are thousands of different neural pathways that can be travelled in the brain.



Synaptic pruning is the elimination of the weakest connections between neurons in the brain's cortex (grey matter). During this adolescent pruning, up to 30 000 synapses may be eliminated each second. Only the connections that experience has shown to be useful are preserved. It is a bit like pruning a tree. The weaker branches are cut back to allow the other branches to flourish.

synaptic pruning the elimination of the least used and hence weakest synapses (connections between neurons) in the brain during adolescence

Your brain uses synaptic pruning to consolidate your learning by pruning away less-travelled connections.

FIGURE 2.67 Before adolescence thousands of new synapses grow, but during adolescence up to 30 000 synapses can be removed per second!

Using technologies such as **positron emission tomography (PET)** scans and fMRI (functional magnetic resonance imaging), scientists can observe growth spurts and losses, and map our brain's activity while we are involved in a variety of experiences.

positron emission tomography (PET) a nuclear medicine imaging technique employing gamma rays to produce a 3D image of a body or functional processes in the body

Increasing the speed of nerve impulses

Your brain myelinates neurons involved in the busy connections so that they become fixed as synaptic pathways. Myelination is the coating of the neurons in a white material called myelin, which speeds up nerve impulses and therefore the speed at which messages are delivered. This process increases in adolescence, decreasing the grey matter of the brain and increasing the white matter. Does this suggest a link between increased cognitive (thinking) abilities and myelination?

Teenage brain development

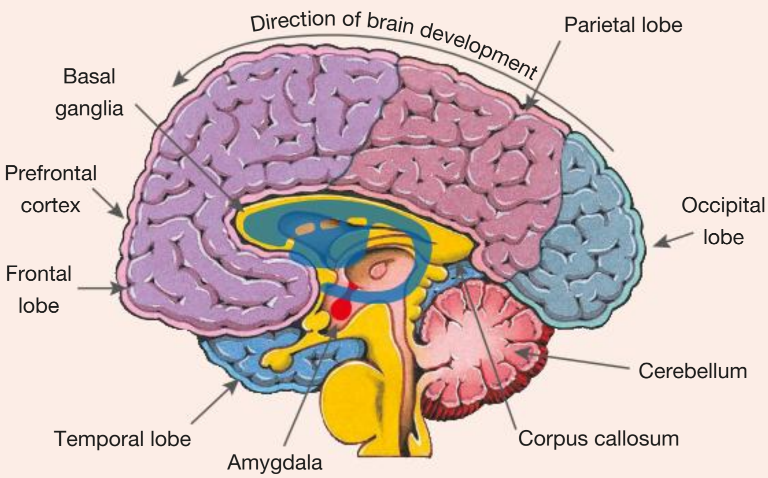
It was once though that brains had finished their development by the end of childhood, but we now know that adolescence is a very busy time for brain growth and change.

- The prefrontal cortex in the brain undergoes a growth spurt at about 11–12 years of age, followed by a period of pruning and organisation of new neural connections. It is often referred to as the 'area of sober thought', and is now thought not to reach full maturity until the age of around 25. The prefrontal cortex is responsible for impulse control, planning, decision making, strategising and judgement.
- The basal ganglia act like a personal assistant to the prefrontal cortex, helping it to prioritise information. They grow neural connections at about the same time as the prefrontal cortex, and then prune them.
- Corpus callosum, the bundle of nerves that connects the left and right hemispheres of the brain, is thought to also be involved in problem solving and creativity. During your teens, the nerve fibres thicken and increase the effectiveness of information processing.
- The amygdala is the emotional centre of your brain. This is the brain's area for primal feelings such as fear and rage. Since a teenager's prefrontal cortex may not yet have matured, they may use their amygdala and associated gut instincts when making decisions. Teenagers also tend to rely more on this part of the brain when processing emotional information, which may lead to impulsive behaviour. Adults are more likely to rely on their more developed and rational prefrontal cortex, which can balance out emotions and impulses from their amygdala.

Back-to-front brain development

Did you know that your brain develops from bottom to top, from back to front, and from right to left? The development of your brain has been 'programmed' for the two tasks that confront survival of the human race (staying alive and getting into the gene pool). In the first 10 years of life, you learn the skills to stay alive. In the next 10 years, you learn how to be a productive and reproductive human. This wiring of your brain is essential to the survival of our species.

FIGURE 2.68 Your brain develops from back to front.



Resources

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2.11 Exercise

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To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Between the ages of about 6–11, neurons grow bushier and make dozens of connections to other neurons, creating new pathways for nerve signals. True or false?
2. MC Identify the name given to the connections between neurons where the message is passed from one neuron to the next.
   A. Axon B. Dendrite C. Myelin D. Synapse
3. MC Identify the part of the brain that acts like a personal assistant to the prefrontal cortex and helps it to prioritise information.
   A. Amygdala B. Basal ganglia C. Cerebellum D. Corpus callosum
4. MC Identify the part of the brain associated with feelings of fear and rage.
   A. Amygdala B. Basal ganglia C. Cerebellum D. Corpus callosum

Apply and analyse

5. Describe the process of synaptic pruning and outline why it is important.
6. Fill in the blanks to complete the following sentence:
   Myelin _________ the speed at which the ____________ can move though the neuron and hence the speed at which the message is communicated.

Evaluate and create

7. SIS Create a timeline outlining the changes in brain development from birth until you turn 20.
8. SIS In 2010, scientists observed fMRI images of participants involved in particular learning activities. Their research results led them to hypothesise that risk-taking in adolescents may be due to over-activity in the mesolimbic dopamine system of their brains. The neurotransmitter dopamine is known to be important for motivation to seek rewards.
   a. Suggest why an increase in dopamine may lead to increased thrill-seeking behaviour and impulsiveness?
   b. Research is still being conducted into this hypothesis. If it is supported, suggest what implications this might have.

Fully worked solutions and sample responses are available in your digital formats.

2.12 Damage to the nervous system

LEARNING INTENTION

At the end of this subtopic you should be able to explain some examples of technological and medical advances in the study of neural diseases and damage.

2.12.1 Paralysis

Damage to the spinal cord of the nervous system may be the result of a disease or an accident or be congenital (already present at birth). Whatever the cause, this type of damage can be devastating and debilitating.

Although there is currently no cure for spinal injury, teams of scientists around the world are involved in research that is aimed at improving the quality of life for those with this injury.

Paralysis and spinal injury

All of the nerves in your peripheral nervous system throughout your body connect to your spinal cord. Damage to this cord can prevent communication of messages between your brain and your body. This loss of communication can lead to **paralysis** (loss of movement).

FIGURE 2.69 Actor Christopher Reeve raised awareness for spinal injury research.

Damage to different parts of the spinal cord results in different types of paralysis. For example, if you were in an accident in which the lower back section of your spine was completely crushed, messages would not be able to travel between your legs and feet and your brain. This loss of communication would mean that you would not be able to sense pain, heat, cold or touch in these parts of your body. You would also be unable to stand or walk as you would not be able to control the muscles in your legs and feet.

Christopher Reeve, an actor who played Superman in the 1970s and 80s, damaged his spinal cord in the neck region in a sporting accident. The consequence was that he was paralysed below the neck and required the use of a machine to breathe air into and out of his lungs as he was unable to breathe for himself. In the years following his accident he raised awareness of spinal injuries and increased public and political interest in related research. He died in 2004 as a result of complications from his paralysis.

Paralysis and disease

A number of diseases can also result in paralysis. One such condition is motor neuron disease. Although the cause of this disease is still unknown, its effects are devastating. While the brain and the senses are usually unaffected, the person with the disease becomes increasingly paralysed.

Motor neuron disease, as the name suggests, targets motor neurons and progressively destroys them. However, sensory neurons remain unaffected. This means that a person paralysed with motor neuron disease could hear and see a mosquito, feel it biting their arm, feel the itchiness, but be unable to move to scratch it or talk to tell someone to scratch it for them.

paralysis loss of the ability to move

motor neuron disease a medical condition that progressively destroys motor neurons, resulting in progressive paralysis but leaving the brain and sense organs unaffected

People with motor neuron disease, such as Stephen Hawking (figure 2.70), sense their environment, but increasingly cannot respond to it. This paralysis eventually involves all muscles within the body. Sadly, motor neuron disease is fatal.

Stephen Hawking was an English theoretical physicist and cosmologist. He was diagnosed at the age of 21 with motor neuron disease (MND). MND soon claimed his physical body and he was confined to a wheelchair but it could never claim his intellect or wit. During his next 55 years he achieved extraordinary successes in the study of the physical nature of the universe especially the theory of special relativity and quantum physics. He died in 2018.

Former Melbourne football coach and Essendon player Neale Daniher also suffers from MND. Daniher lead the way raising funds for research into treatment and cures through the Big Freeze at the 'G for Fight MND. Other challenges, such as the Ice Bucket challenge, raised funds for MND.

FIGURE 2.70 Stephen Hawking suffered from motor neuron disease.

FIGURE 2.71 The Big Freeze at the 'G, started by Neale Daniher in 2019

Stem cells — A possible treatment?

Embryonic stem cells have many properties that scientists find exciting. They can produce new cells for longer than other cells, and under the right conditions they can be made to differentiate into particular cell types. Some current research is investigating the injection of nerve cells produced from embryonic stem cells into the site of spinal injury. Although it is early days for this research, it is hoped that it may lead to the recovery of muscle function in some cases.

Although the possible applications of this research are exciting, technologies involving the use of human embryonic stem cells must undertake strict bioethical procedures. The human embryos used in this research are obtained from the surplus embryos of couples undergoing IVF treatment.

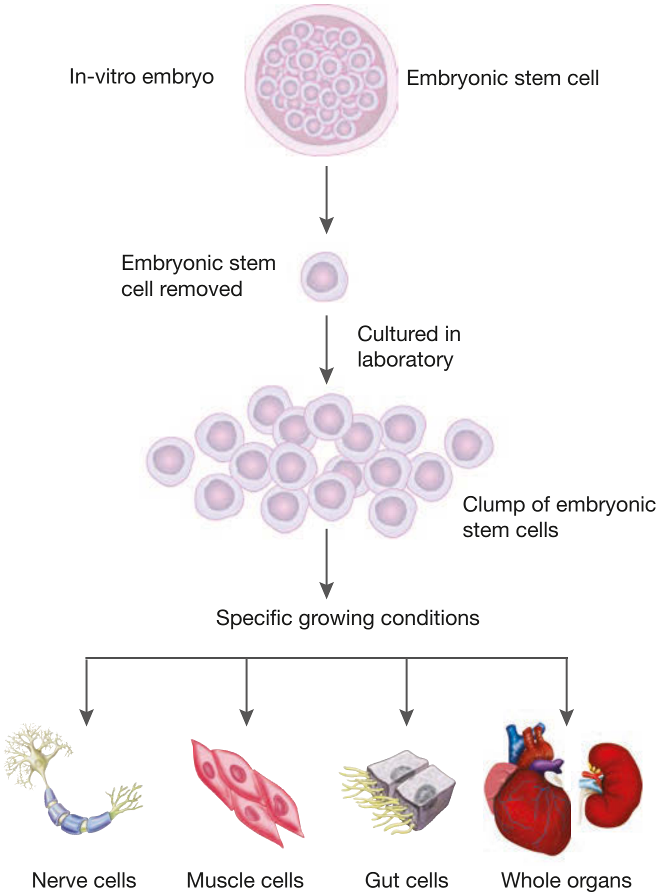


FIGURE 2.72 The use of stem cells to treat (and possibly even cure) a variety of diseases is being investigated.

Brain-control interface technology

Currently making an entrance into the mass market are games and toys that utilise **brain-control interface technology**. In these applications, computer software in 'mindsets' are used to decode brain wave patterns and facial movements to bring about particular responses in the external environment (for example, moving an object by just thinking about it).

Broader applications of this technology, such as **implanted electrodes** and **neural prostheses**, are being researched and developed in order to provide assistance to people with a variety of disabilities. There have already been cases in which paralysed people have been able to move their wheelchairs by just thinking about the movement, or those who are unable to talk have been able to use their brain to result in their thoughts being spoken aloud. Cochlear implants are also examples of neural prostheses used to stimulate the auditory nerve in individuals with hearing loss.

FIGURE 2.73 Brain-control interface technology has many possible applications.

brain-control interface technology a direct communication pathway between the brain and an external device

implanted electrodes technological devices that have a number of medical applications, such as their direct connection to a human brain, with the aim of providing assistance to people with a variety of disabilities

neural prostheses technological devices that can replace a motor, sensory or cognitive structure

DISCUSSION

How else might brain-control interface technology be used? What other senses could be assisted using this technology? Could it be used to enable us to experience senses that humans do not currently possess?

on Resources

Weblinks Stem cells
Fight MND

assesson Additional automatically marked question sets

2.12 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

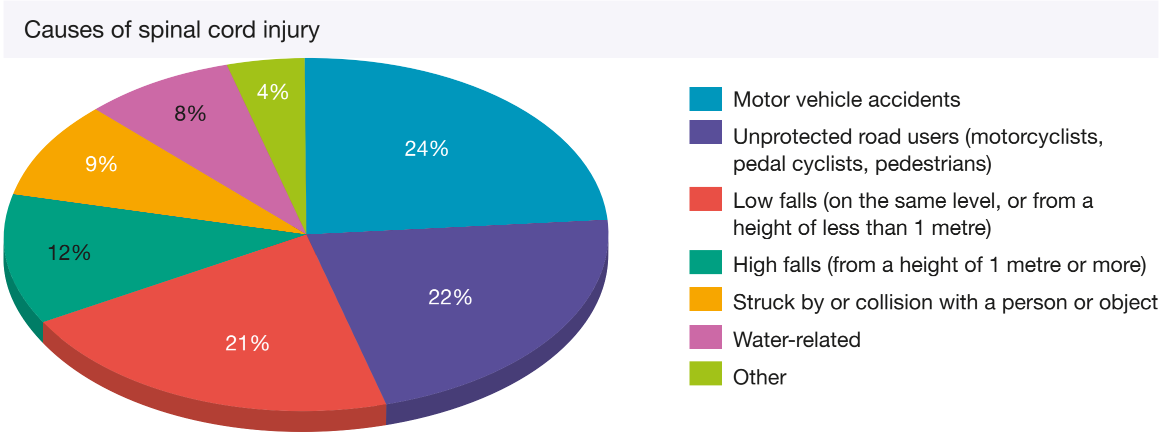
1. Define the term *paralysis*.
2. Outline the properties that make stem cells interesting to researchers.
3. Outline the cause and symptoms of motor neuron disease.

Apply and analyse

4. Describe evidence that suggests that stem cells may one day be used to restore some mobility after a spinal injury.
5. Outline how brain-control interface technology can bring about body responses.
6. Describe an application of implanted electrodes or neural prostheses.

Evaluate and create

7. **SIS** Use the graph showing the causes of spinal injury to answer the following questions.
   a. What are the two leading causes of spinal injury?
   b. What percentage of spinal injuries are sports related? Suggest which sports might have the highest risk of spinal injury.



8. a. Explain why an injury in the neck region of the spinal cord may result in quadriplegia, whereas an injury in the lower back region of the spinal cord may result in paraplegia.
   b. Research treatment options that are being investigated for different types of spinal cord injury.

Fully worked solutions and sample responses are available in your digital formats.

2.13 Studying the brain

LEARNING INTENTION

At the end of this subtopic you will be able to describe how different technologies can be used to create images of the brain and how developments in neurotechnology have shown that brains and brain connections change due to outside stimulus.

SCIENCE AS A HUMAN ENDEAVOUR: Your amazing brain

Your brain is amazing, mysterious and powerful. While you use it to formulate, ask and investigate questions, sometimes these questions are about the brain itself! What do you know about your brain? Why not open your brain up to new ideas, new discoveries and new questions about brains?

Throughout history, humans have asked many questions about the human brain and there have been varied theories about its structure and how it works. Some questions have been about how brain cells interact with each other and what happens when the brain grows, ages or is damaged. Other questions relate to how it is involved in our learning, experiences and emotions, or how it contributes to make us who we are. There have even been investigations to design and construct artificial brains!

Early research into brains

Frantz Joseph Gall, a German physician, developed the theory of phrenology in 1796. He believed the size, shape and bumps of a person's skull determined their character and mental capacity. Popular between 1810 and 1840, phrenology is now dismissed as a **pseudoscience**. However, some of its assumptions are still valid. The idea that mental processes can be localised in the brain is one such claim and is supported by our modern neuroimaging techniques. The word phrenology comes from the Greek terms *phren*, meaning 'mind', and *logos*, meaning 'knowledge'.

pseudoscience an apparently scientific approach to a theory that on close analysis is shown to have no scientific validity

Guillaume-Benjamin-Amand Duchenne de Boulogne (1806–1875) was a French neurologist who greatly advanced the science of muscular electrophysiology and electromyography. In 1835, he began experimenting on therapeutic electropuncture — which involved applying an electric shock under the skin with sharp electrodes to stimulate the muscles. This increased his understanding of the conductivity of neural pathways. Some refer to Guillaume as the father of modern neurology and in recognition of his research (and discovery), Duchenne muscular dystrophy is named after him.

FIGURE 2.74 Joseph Gall focused on phrenology, which also explored different divisions of the skull.

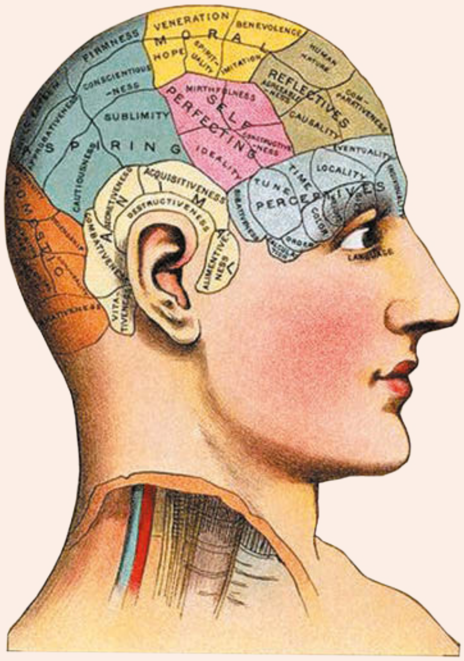


FIGURE 2.75 Duchenne and an assistant give a demonstration of the mechanics of facial expression using electropuncture.

Emerging brain science

Our interest in brains has given rise to a variety of new branches of science. Examples of these include neurobiology, neuroscience, neurophysiology, neuropsychology and neuroanatomy. The frontiers of brain science also require an integrated approach that combines approaches and technologies from various scientific fields. Scientists in medical, biological, molecular biological, theoretical science, psychology, biophysics and various computer technologies can all be involved in trying to find out more about particular aspects of our brains.

Brain imaging

It is no wonder that some scientific terms are often referred to in an abbreviated form. This is especially the case with some of the names of imaging technologies used to look at the structure and function of the brain.

- **Computerised axial tomography (CAT)** and magnetic resonance imaging (MRI) produce computer images of the brain's internal structure.
- Scanning technologies that provide information about brain function include: electroencephalography (EEG); **magnetoencephalography (MEG)**; positron emission tomography (PET); functional magnetic resonance imaging (fMRI); and **functional magnetic resonance spectroscopy (fMRS)**.

A key advantage of these scanning technologies is that they can analyse the brain while its owner is alive — and using it!

computerised axial tomography (CAT) a medical imaging technology employing x-rays to produce a 3D image of a body using computer processing

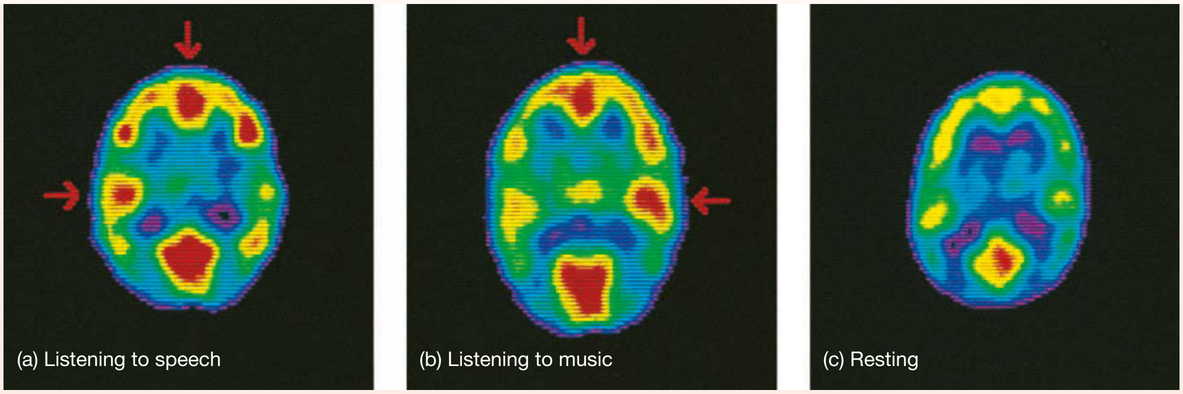
magnetoencephalography (MEG) a medical imaging technique for mapping brain activity by recording magnetic fields produced by electrical currents occurring naturally in the brain

functional magnetic resonance spectroscopy (fMRS) a medical imaging technique used to measure levels of different metabolites in body tissues

PET

PET was the first technology used to observe brain functions. It involves injection of a radioactive solution into the brain. The amount of radiation measured in particular regions indicates levels of activity in those parts at that time.

FIGURE 2.76 PET scans of people with normal brain activity participating in different tasks. Red indicates the greatest level of brain activity, whereas blue indicates the brain areas that are least active.



EEGs and MEGs

EEGs and MEGs involve the attachment of multiple electrodes to be the scalp and the measurement of either electrical or magnetic activity occurring in the brain during mental processing. These technologies record activation of groups of neurons responding to a specific event and help to determine how quickly this occurs in the brain.

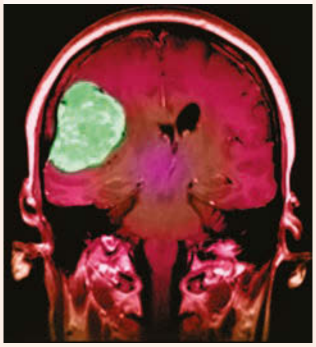
fMRI and fMRS

Areas in your brain involved in thinking require more oxygen than the parts not involved. This oxygen is transported by haemoglobin, a molecule that contains iron, which is magnetic.

fMRI uses a large magnet to compare the amount of oxygenated haemoglobin entering brain cells with the amount of deoxygenated haemoglobin that is leaving them. The computer-generated images colour the regions with greater oxygenated blood. This allows the pinpointing of the activated brain regions to be located within a centimetre.

While fMRS uses the same equipment as fMRI, it uses different computer software. This technology can record and identify levels of specific chemicals during brain activity and has been used to study language function in the brain.

FIGURE 2.77 MRI scan of a benign brain tumour



Neurotechnology

We have learned more about the human brain in the past 10–15 years than we have in the rest of recorded history. This new information is leading revolutionary changes in how we use our brains and think about them. New technologies are providing us with new knowledge about the brain and how it works. With new knowledge, previously held ideas often need to be modified. In some cases, the previous understanding or theories have needed to be discarded completely so that new theories can be developed to replace them.

Neuroplasticity and neurogenesis

Contrary to what was believed in the past, our brains and brain connections, or neural pathways, are not static and unchanging. They are constantly wiring and rewiring. Stimulation and challenging your brain encourages the growth of dendrites and the production of new neurons. Lack of stimuli can result in weakening of existing connections and possible pruning of them. You may also lose new neurons in the process.

Currently there are some exciting research projects on **neurogenesis** (meaning 'the birth of new neurons'). This research is investigating whether factors such as exercise and different moods can influence how many neurons are being 'born' each day and how many survive.

neurogenesis the creation of neurons

FIGURE 2.78 Technologies provide us with information that enables us to develop models so that the knowledge can be communicated to others.

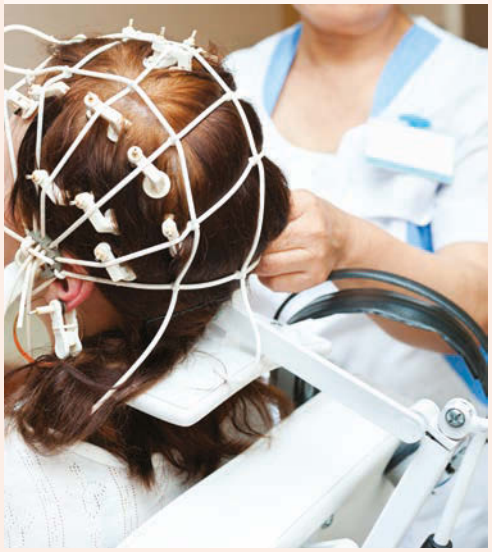


FIGURE 2.79 A technician monitoring a patient undergoing an MRI scan of the brain

TABLE 2.8 PMI chart on neurotechnology

Plus	Minus	Interesting
• **New medicines** For example, these may be individually styled and used to cure or treat mental illnesses with high efficacy and negligible side effects. This may lead to a major decrease in mental illnesses such as depression, schizophrenia, bipolar disorders, substance abuse and obsessive–compulsive disorders.	• **New weapons** For example, neuroweapons that influence how the brain (and person) responds to particular stimuli or situations	• **Neuroeducation** For example, a tablet to ingest or a connection to an implant in your brain to pass on the knowledge of a new language, topic or skill

(continued)

TABLE 2.8 PMI chart on neurotechnology *(continued)*

Plus	Minus	Interesting
• **New chemicals** For example, chemicals that may be ingested to: • influence learning, memory processes, decision making and attention • influence moods, motivation, feelings and awareness • restore and extend the capacity of our senses (enhancing the sense of sight, hearing, smell or taste)	• **New marketing strategies** For example, neuromarketing that uses knowledge of the brain to prioritise their products over others	• **Neuromodulators** For example, a tablet to ingest to help people feel happy all of the time

The future of neurotechnology

Our society shapes the development of new technologies. It is also shaped by these technologies. Discoveries in neurotechnology have been enhanced by developments in information technologies. Development of nanobiochips and brain-imaging technologies increase the accuracy of biological and neurological analysis. Nano-imaging techniques will enable analysis of events at the neuromolecular level in the brain. Knowledge of these events will enhance our understanding about how our brains work and give us power to modify their function.

In the future, neurotechnology may provide us with knowledge that may lead to the development of new treatments for diseases, new industries — and new problems to consider and solve. How will new neurotechnologies change human societies? How will they change us?

on Resources

Video eLesson An MRI scan (eles-4186)

assesson Additional automatically marked question sets

2.13 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. **MC** Identify the first technology used to observe brain functions, which involved injection of a radioactive solution into the brain and measuring the amount of radiation in particular regions to indicate the levels of activity at that time.
   A. CAT **B.** EEG **C.** PET **D.** MRI
2. **MC** Identify the type of technology involved in the attachment of multiple electrodes to the scalp and measurement of magnetic activity occurring in the brain during mental processing.
   A. MEG **B.** PET **C.** EEG **D.** CAT

3. Identify the abbreviation for each of the processes listed below:
   a. Computerised axial tomography
   b. Electroencephalography
   c. Functional magnetic resonance imagining
   d. Functional magnetic resonance spectroscopy
   e. Magnetic resonance imaging
   f. Position emission tomography
4. Phrenology has a colourful history and varied interpretations. Give an example of how it has been used.

Apply and analyse

5. Identify the technology that uses a large magnet to compare the amount of oxygenated haemoglobin entering brain cells with the amount of deoxygenated haemoglobin that is leaving them. Why is this technology useful?
6. Match the name of the brain imaging technique to its description.

Term	Definition
a. CAT	A. Reports on patterns of electrical transmission within an active brain, which are seen as a squiggly line graph
b. MRI	B. Responds to small magnetic fields caused by an electrical current of firing neurons and can identify the source of electrical activity
c. EEG	C. Records electrical activity in defined areas, using colour to represent positive and negative locations in the cerebral cortex
d. PET	D. Image that focuses on soft tissue and can show differences in chemical composition

7. Phrenology is considered by many to be a pseudoscience. What is meant by the term *pseudoscience*?
8. Describe the difference between neurogenesis and neuroplasticity.

Evaluate and create

9. Research ways in which the development of imaging technologies has improved our understanding of the structure and function of the human brain.

10. **SIS** There are claims that brain scans can reveal personality types and the type of career you are best suited for. Research these claims.
    a. On the basis of your findings, do you agree that brain scans are capable of this? Justify your response.
    b. Find out about issues related to the use of brain scans in this way. Do you agree with their use for this purpose? Explain why.
11. **SIS** If you were to hear about a new model or theory about the brain in the media, describe how you would use scientific knowledge to determine its possible validity.
12. **SIS** Research neuro-linguistic programming (NLP) and the claims that it helps people lead better lives. Summarise your findings.

Fully worked solutions and sample responses are available in your digital formats.

2.14 Review

Access your topic review eWorkbooks

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-5133	ewbk-5135	ewbk-5137

on Resources

2.14.1 Summary

Coordination and control

- Multicellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment.
- Homeostasis is the constant maintenance of the internal body environment. Variables such as blood glucose, water and carbon dioxide need to be kept within a particular range for the body to remain healthy.
- The stimulus–response model is where any changes (stimuli) are detected (by receptors) leading to the initiation of a response by various body parts.
- Negative feedback occurs when the response is in an opposite direction to the stimulus.
- Both the endocrine and nervous systems work together to help maintain homeostasis and allow for responses to occur.

The nervous system — fast control

- The nervous system is composed of the central nervous system (CNS), which contains your brain and spinal cord and the peripheral nervous system (PNS), which contains the nerves (neurons) that connect to the rest of the body.
- There are three types of neurons: sensory, interneuron and motor neuron.
- A synapse is a gap between neurons and is where neurotransmitters are released. Neurotransmitters are chemicals involved in passing messages between your neurons.
- Neurons are made up of three main parts: the dendrites, cell body and axon.
- Reflex responses require no conscious thought. A reflex arc is the nerve pathway followed by the reflex action.

Getting the message

- Sense organs detect stimuli (such as light, sound, touch, taste and smell) in your environment. Examples of human sense organs are your eyes, ears, skin, tongue and nose.
- Receptors respond to different stimuli. Receptors include thermoreceptors, mechanoreceptors, chemoreceptors, photoreceptors and pain receptors.

The brain

- The brain is made up of three main parts: the forebrain (cerebrum, thalamus), the midbrain (reticular formation) and the hindbrain (medulla, pons and cerebellum).
- The reticular formation helps regulate your alertness (from being fully awake or deeply asleep), motivation, movement and some of your reflexes.

The endocrine system — slow control

- Your endocrine system is composed of endocrine glands that secrete chemical substances called hormones into the bloodstream.
- Hormones control and regulate functions such as metabolism, growth, development and sexual reproduction.

Plant hormones

- Plant hormones coordinate the way plants grow, develop and respond to their internal and external environments.
- The five main plant hormones are auxins, cytokinins, gibberellins, abscisic acid and ethylene.
- Plants have internal biological clocks and may have different patterns of movement in a 24-hour cycle. This is known as a circadian rhythm or cycle.

Emotions and the limbic system

- Your 'emotional brain' or limbic system is made up of a collection of structures within your brain. The limbic system is involved in memory, controlling emotions, decision making, motivation and learning.
- Neurotransmitters such as serotonin, noradrenaline and dopamine affect how individuals feel and react.
- The fight-or-flight response is a physiological reaction occurring in response to perceived attacks or threats. It involves the hormone adrenaline from the adrenal gland.

Memory

- Incoming information is filtered through your sensory register.
- Information that has made it past your thalamus forms your immediate memory. Memories that capture your focus move into your working memory. From here, information may go to your hippocampus and move into long-term memory.

Sleep

- Melatonin, released from your pineal gland, is important in aiding sleep and making you drowsy.
- During the night, your body experiences sleep cycles lasting 90–110 minutes, with periods of REM (dream sleep triggered by the pons) and non-REM sleep.

The teen brain

- The brain continues to develop through adolescence; any connections not used are eliminated through synaptic pruning.

Damage to the nervous system

- Paralysis is the loss of movement that can result from damage to the nervous system, particularly the spinal cord.
- Motor neuron disease targets motor neurons, resulting in progressive paralysis.

Studying the brain

- There are many techniques to examine the brain through imaging — magnetic resonance imaging (MRI) and computerised axial tomography (CAT) produce computer images of the brain's external structure.
- Scanning technologies that provide information about brain function include: electroencephalography (EEG); magnetoencephalography (MEG); positron emission tomography (PET); functional magnetic resonance imaging (fMRI); and functional magnetic resonance spectroscopy (fMRS).

2.14.2 Key terms

abscisic acid a plant hormone that is involved in the process of development
acetylcholine produced in vesicles in a neuron, this neurotransmitter is released on the arrival of a nervous impulse to travel across the synapse (gap between neurons) to stimulate an impulse in another neuron
adrenal glands a pair of glands situated near the kidneys that release adrenaline and other stress hormones
adrenaline a hormone secreted in response to stressful stimuli, which readies your body for the fight-or-flight response
alpha (α) waves waves of electrical impulses emitted by your brain at a frequency of 8–12 Hz associated with being calm, relaxed but aware of your environment
amygdala emotional centre of the brain, which processes primal feelings such as fear and rage
auditory nerve a large nerve that sends signals to the brain from the hearing receptors in the cochlea

auxin plant hormone that regulates or modifies the growth of plants such as promoting stem growth, cell expansion and repair
axon long structure within a neuron through which the nervous impulse travels from the dendrite and the cell body
beta (β) waves waves of electrical impulses emitted by your brain at a frequency of 13–30 Hz associated with being strongly engaged and using many of your senses, and perhaps with anxiety
brain-control interface technology a direct communication pathway between the brain and an external device
brain stem the part of the brain connected to the spinal cord, responsible for breathing, heartbeat and digestion
cell body part of a neuron that contains the nucleus
central nervous system the part of the nervous system composed of the brain and spinal cord
cerebellum the part of the brain that controls balance and muscle action
cerebral cortex the outer, deeply folded surface of the cerebrum
cerebral hemispheres the left and right halves of the brain
cerebrum the largest part of the brain responsible for higher order thinking, controlling speech, conscious thought and voluntary actions
chemoreceptors special cells within a sense organ that are sensitive to particular chemicals
circadian rhythm the 24-hour pattern of behaviour exhibited in animals and plants even if deprived of environmental changes
cochlea the snail-shaped part of the inner ear in which receptors are stimulated
cognition another name for thinking or mental activity
colour blindness an inherited condition, more common in males, in which a deficiency of one or more of the different types of cones may mean that you find it difficult to see a particular colour or combinations of colours
computerised axial tomography (CAT) a medical imaging technology employing x-rays to produce a 3D image of a body using computer processing
cones photoreceptors located in the retina that respond to red, green or blue light
cornea the curved, clear outer covering of your eye
corpus callosum a bridge of nerve fibres through which the two cerebral hemispheres communicate
corpus luteum an endocrine structure that is involved in the production of progesterone
cytokines signalling molecules that regulate the function between cells of the immune system
cytokinin hormone that promotes cell division in plants
cytosol the fluid found inside cells
delta (δ) waves waves of electrical impulses emitted by your brain at a frequency of 1–3 Hz associated with being in a deep, dreamless sleep
dendrite structure that relays information towards the cell body of a neuron
dopamine a neurotransmitter involved in producing positive moods and feelings.
ear canal the tube that leads from the outside of the ear to the eardrum
eardrum a thin piece of stretched skin inside the ear that vibrates when sound waves reach it
effectors organs that respond to a stimuli to initiate a response
electroencephalogram (EEG) a device that detects and records the electrical activity of the brain
empathy the capacity to recognise and to some extent share feelings that are being experienced by other people
endocrine glands organs that produce hormones, which are released into the bloodstream
endocrine system the body system composed of different glands that secrete signalling molecules (hormones) that travel in the blood for internal communication and regulation and to maintain homeostasis
ethylene gaseous plant hormone involved in the ripening of fruits and the lowering and dropping (abscission) of leaves
fertilisation fusion of the male sex cell (sperm) and the female sex cell (ovum)
follicles found in the ovary and contain a single immature ovum (egg)
follicle-stimulating hormone (FSH) regulates the development, growth and reproductive processes of the body
forebrain consists of the cerebrum, cerebral cortex, thalamus and hypothalamus
functional magnetic resonance imaging (fMRI) a type of specialised MRI scan used to measure the change in blood flow related to neural activity in the brain or spinal cord
functional magnetic resonance spectroscopy (fMRS) a medical imaging technique used to measure levels of different metabolites in body tissues
gibberellin plant hormone that regulates growth, including germination and dormancy
glucagon a hormone, produced by the pancreas, which increases blood glucose levels
glycogen the main storage carbohydrate in animals, converted from glucose by the liver and stored in the liver and muscle tissue

higher-order thinking involves problem solving and decision making
hindbrain a continuation of the spinal cord
hippocampus part of the brain with a key role in consolidating learning, comparing new information with previous experience, and converting information from working memory to long-term storage
homeostasis the maintenance by an organism of a constant internal environment (for example, blood glucose level, pH, body temperature)
hormone a signalling molecule that is produced in specialised cells and travels in blood to act on target cells to cause a specific response
hypothalamus a part of the forebrain that monitors internal systems and coordinates the nervous and endocrine systems to maintain homeostasis
implanted electrodes technological devices that have a number of medical applications, such as their direct connection to a human brain, with the aim of providing assistance to people with a variety of disabilities
insulin hormone that reduces blood glucose levels
interneuron a nerve cell that conducts a nerve impulse within the central nervous system, providing a link between sensory and motor neurons
iris coloured part of the eye that opens and closes the pupil to control the amount of light that enters the eye
lens a transparent curved object that bends light towards or away from a point called the focus
limbic system a collection of structures within your brain involved in memory, controlling emotions, decision making, motivation and learning
long-sightedness (hyperopia) the condition of not being able to see clearly things that are close
luteinising hormone (LH) hormone produced by the anterior pituitary gland that initiates ovulation, the production of progesterone and corpus luteum development in females and in the stimulation of production of testosterone in testes in males
magnetic resonance imaging (MRI) a medical imaging technique employing a powerful magnetic field and radio waves to produce a 3D image of a body
magnetoencephalography (MEG) a medical imaging technique for mapping brain activity by recording magnetic fields produced by electrical currents occurring naturally in the brain
mechanoreceptors special cells within the skin, inner ear and skeletal muscles that are sensitive to touch, pressure and motion
medulla oblongata (medulla) a part of the brain developed from the posterior portion of the hindbrain
melatonin hormone produced by the pineal gland that is involved in sleepiness
menstruation monthly discharge of blood and other materials from the uterus lining through the vagina (also known as period)
middle ear the section of the ear between your eardrum and the inner ear, containing the ossicles
mirror neurons group of neurons that activate when you perform an action and when you see or hear others performing the same action
motor neuron a nerve cell that conducts a nerve impulse from the central nervous system to the effector, such as a muscle or gland so that it may respond to a stimulus
motor neuron disease a medical condition that progressively destroys motor neurons, resulting in progressive paralysis but leaving the brain and sense organs unaffected
multicellular organism a living thing that is composed of many cells
myelin a fatty, white substance that encases the axons of neurons
myelination the process of neurons becoming coated in a myelin sheath
negative feedback a homeostatic mechanism that returns a stimulus back within its normal range
nerve a bundle of neurons
nervous system the body system in which messages are sent as electrical impulses (along neurons) and chemical signals (neurotransmitters across synapses)
neural prostheses technological devices that can replace a motor, sensory or cognitive structure
neurogenesis the creation of neurons
neuron another name for nerve cell, a specialised cell for transmitting a nerve impulse
neurotransmitters signalling molecules released from the axon terminals into the synapse between nerve cells (neurons)
noradrenaline also called norepinephrine; common neurotransmitter involved in arousal states
nucleus roundish structure inside a cell that acts as the control centre for the cell
oestrogen hormone secreted from the ovaries and the placenta with a variety of effects such as inducing puberty changes and thickening of the uterus lining
olfactory nerve nerve that sends signals to the brain from the chemoreceptors in the nose

optic nerve large nerve that sends signals to the brain from the sight receptors in the retina
organelle small structure in a cell with a special function
ossicles a set of three tiny bones that send vibrations from the eardrum to the inner ear
ovulation the release of an ovum
ovum female sex cells produced in the ovaries
oxytocin a hormone that induces labour and milk release from mammary glands in females
pain receptors special cells located throughout the body (except the brain) that send nerve signals to the brain and spinal cord in the presence of damaged or potentially damaged cells
pancreas a large gland in the body that produces and secretes the hormone insulin
papilla bumps on your tongue that are thought to contain tastebuds
paralysis loss of the ability to move
peripheral nervous system the part of the nervous system containing nerves that connect to the central nervous system
photoreceptor a special cell located in your eye that is stimulated by light
pineal gland gland that produces the hormone melatonin, which can make you feel drowsy
pituitary gland a small gland at the base of the brain that releases hormones
pons part of the brain involved in regulating sleep, arousal and breathing, and coordinating some muscle movements
positive feedback a homeostatic mechanism that enhances the original stimulus
positron emission tomography (PET) a nuclear medicine imaging technique employing gamma rays to produce a 3D image of a body or functional processes in the body
primacy remembering the first time that you do something, or the beginning of something
progesterone hormone produced in the ovaries that inhibits ovulation and prepares the lining of the uterus for pregnancy
pseudoscience an apparently scientific approach to a theory that on close analysis is shown to have no scientific validity
pupil a hole through which light enters the eye
recency remembering the last time that you do something, or the end of something
reflex arc a quick response to a stimulus that does not involve the brain (for example, knee jerk). The message travels from receptor to sensory neuron to interneuron in the spinal cord then directly via the motor neuron to the effector.
reticular formation a network of neurons that controls the amount of information that flows into and out of the brain
retina curved surface at the back of the eye
rods photoreceptors located in the retina that respond to low levels of light and allow you to see in black and white in dim light
sense organ a specialised structure that detects stimuli (such as light, sound, touch, taste and smell) in your environment
sensory neuron a nerve cell in the sensory organs that conducts a nerve impulse from receptors to the central nervous system
sensory register part of the information processing model of the brain that involves filtering incoming information
serotonin a common neurotransmitter involved in producing states of relaxation and regulating sleep and moods
short-sightedness (myopia) the condition of not being able to see clearly things that are far away
stimulus–response model a system in which a change (stimulus) is detected by receptors leading to a response, which acts to alter and return the variance to normal
suprachiasmatic nucleus (SCN) the biological clock, located in the hypothalamus near where the optic nerves cross
synaesthesia a condition in which a sensation is produced in one physical sense when a stimulus is applied to another
synapse the gap between adjoining neurons where neurotransmitters travel
synaptic pruning the elimination of the least used and hence weakest synapses (connections between neurons) in the brain during adolescence
tastebuds nerve endings located in your tongue allowing you to experience taste
testosterone male sex hormone
thalamus part of the brain through which all sensory information from the outside (except smell) passes before going to other parts of the brain for further processing

thermoreceptors special cells located in your skin, part of your brain and body core that are sensitive to temperature
thermoregulation the control of body temperature
thermostat a device that establishes and maintains a desired temperature automatically
thyroid gland a small gland in the neck that helps regulate metabolism and growth
uterus the organ in which a baby grows and develops
vesicle a small fluid-filled, membrane-bound sac in a cell

on Resources

eWorkbooks	Study checklist (ewbk-5139) Literacy builder (ewbk-5140) Crossword (ewbk-5142) Word search (ewbk-5144)
Practical investigation eLogbook	Topic 2 Practical investigation eLogbook (elog-0625)
Digital document	Key terms glossary (doc-34973)

2.14 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 3, 5, 12, 13, 15	Questions 2, 6, 8, 10, 11, 16	Questions 4, 7, 9, 14, 17, 18

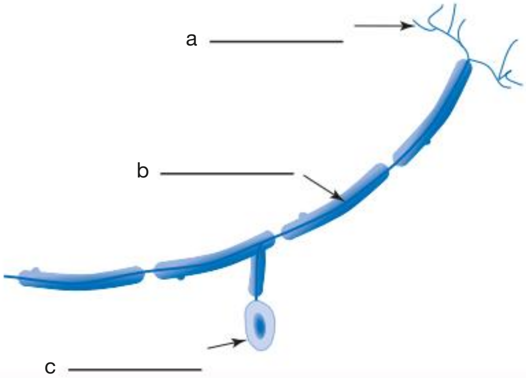
Remember and understand

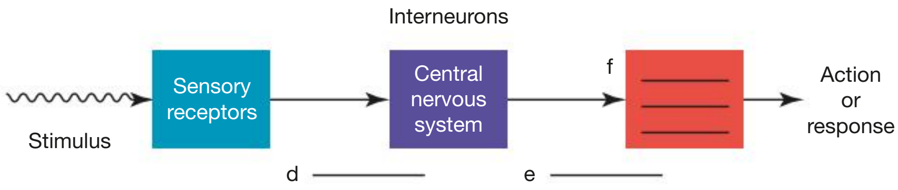
1. Construct a flow chart to show the stimulus–response model.
2. Copy and complete the following table.

TABLE Stimuli, receptors and sense organs

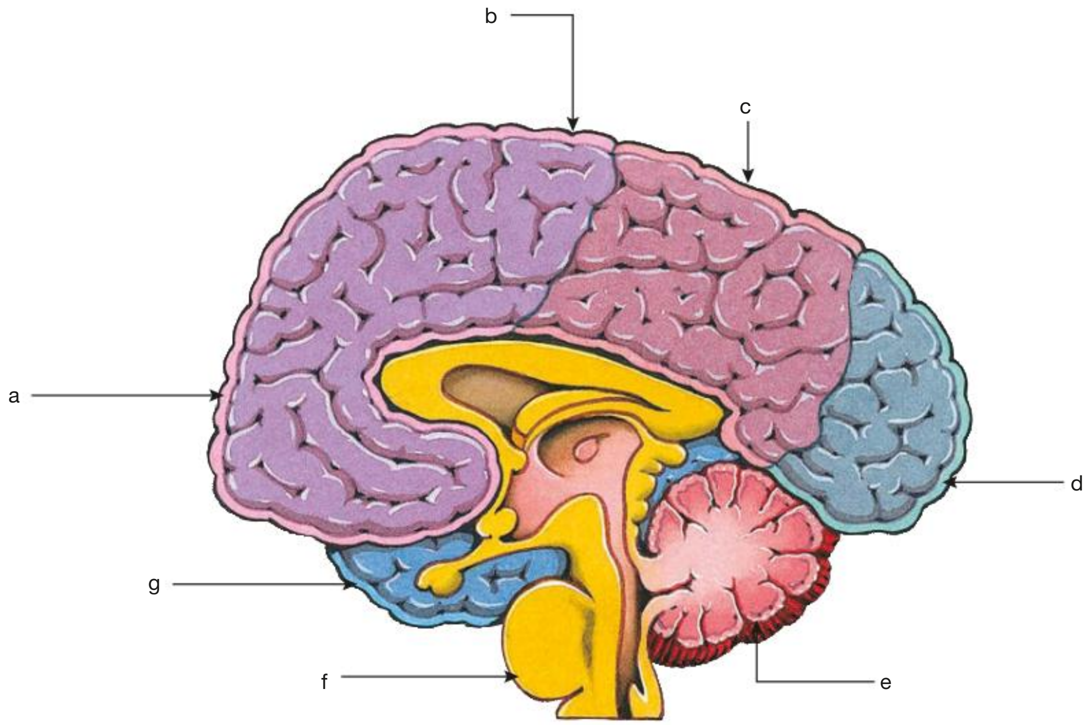
Stimulus	Receptor	Sense organ
		Eye
	Chemoreceptor	
Vibrations, pressure		
	Thermoreceptor	

3. Place the following labels in the correct places on the diagrams provided.
   - dendrite
   - sensory neurons
   - cell body
   - effector
   - axon
   - motor neurons





4. Label each of the parts of the brain and state one of the functions of each.



5. Match the hormone with the appropriate function.

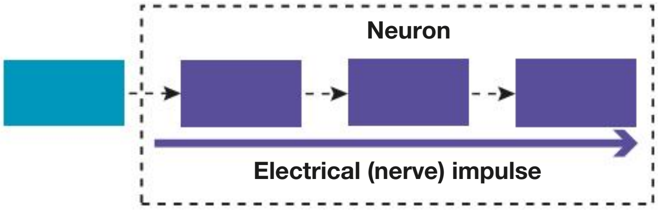
Hormone	Function
a. Anti-diuretic hormone (ADH)	**A.** Causes reabsorption of water in kidneys
b. Glucagon	**B.** Causes testes to produce sperm
c. Insulin	**C.** Causes thickening of the uterine lining
d. Oestrogen	**D.** Controls menstruation cycle and pregnancy
e. Progesterone	**E.** Increases blood glucose levels
f. Testosterone	**F.** Increases metabolic rate of cells
g. Thyroxine	**G.** Lowers blood glucose levels

6. Match the terms with their appropriate description in the table provided.

Term	Description
a. Central nervous system	A. Made up of a cell body, dendrites and axon
b. Motor neuron	B. Takes messages away from the central nervous system
c. Nerves	C. Takes messages to the central nervous system
d. Neuron	D. Brain and spinal cord
e. Neurotransmitter	E. Chemical messenger that carries messages from one neuron to another across a synapse
f. Peripheral nervous system	F. Nerves that connect the central nervous system to the rest of the body
g. Sensory neuron	G. Gap between neurons
h. Synapse	H. Made up of neurons

Apply and analyse

7. Underline the incorrect term in each sentence and replace it with the correct term. Write definitions of the incorrect words you replaced.
   a. The neuron carries hormones to target cells.
   b. The master gland of the endocrine system is the adrenal gland.
   c. The brain and spinal cord make up the peripheral nervous system.
   d. Each molecule has tissues that carry out particular functions.
8. Outline the function of auxins and gibberellins in plants and state where each is produced.
9. Outline the differences between each pair of terms.
   a. Positive feedback and negative feedback
   b. Thermoreceptor and chemoreceptor
   c. Axon and dendrite
   d. Hormone and neurotransmitter
   e. CNS and PNS
   f. Thalamus and hypothalamus.
10. Place the terms in their appropriate position in the flow chart: cell body, axon, dendrite, stimulus

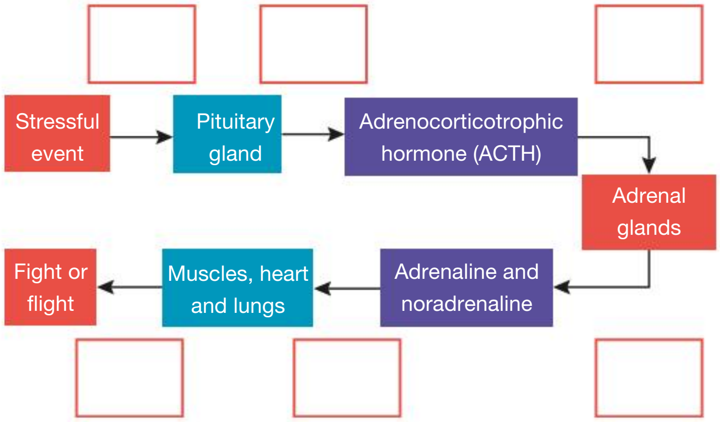


11. Describe the relationship between adrenaline, pituitary, adrenal cortex, heart rate, stress.
12. Recall three endocrine glands and hormones they produce. Describe a function of each of the hormones.
13. Provide an example of a negative feedback mechanism. Explain why it is important.
14. Explain the following types of brain imaging and describe the use of each.
    a. Computerised axial tomography (CAT)
    b. Electroencephalogram (EEG)
    c. Magnetic resonance imaging (MRI)
    d. Positron emission tomography (PET)

Evaluate and create

15. Construct a table to summarise the differences between the nervous and endocrine systems. Make sure you include the name of the information each system produces, how that information is carried throughout the body, and the speed and length of each system's response.
16. Draw a flow chart that outlines what happens when you sit down on a chair that has a sharp object on it. Include both nervous and endocrine responses.

17. The flow chart shows a series of events that may occur when you encounter a stressful event. Suggest descriptions or labels for each of the links (shown as the blank boxes)



18. Explain the role of the nervous and endocrine system in regulating body temperature and outline both voluntary and involuntary processes involved in thermoregulation.

Fully worked solutions and sample responses are available in your digital formats.

on Resources

eWorkbook Reflection (ewbk-3038)

teachon

Test maker
Create customised assessments from our extensive range of questions, including teacher-quarantined questions.
Access the assignments section in learnON to begin creating and assigning assessments to students.

RESOURCE SUMMARY

on Resources

Below is a full list of **rich resources** available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

2.1 Overview

eWorkbooks
- Topic 2 eWorkbook (ewbk-5090)
- Student learning matrix (ewbk-5092)
- Starter activity (ewbk-5093)

Practical investigation eLogbook
- Topic 2 Practical investigation eLogbook (elog-0625)

Video eLesson
- Neurons in the brain (eles-2631)

Weblink
- Reaction time test

2.2 Coordination and control

eWorkbook
- The stimulus–response model (ewbk-5095)

2.3 The nervous system — fast control

eWorkbooks
- Labelling a neuron (ewbk-5146)
- Labelling a synapse (ewbk-5099)
- Labelling the reflex arc (ewbk-5101)
- The nervous system (ewbk-5103)

Practical investigation eLogbook
- Investigation 2.1: How good are your reflexes? (elog-0627)

Video eLessons
- The human nervous system (eles-2632)
- Brain cell synapse (eles-2634)

Interactivities
- A nervous response (int-0670)
- A bundle of nerves (int-0015)
- Neuron structure (int-5762)

2.4 Getting the message

eWorkbooks
- Labelling the eye (ewbk-5105)
- Labelling the ear (ewbk-5107)
- Skin (ewbk-5109)

Practical investigation eLogbooks
- Investigation 2.2: Touch receptors on your skin (elog-0629)
- Investigation 2.3: Dissection of a mammal's eye (elog-0631)

Video eLessons
- Human eye anatomy and common eye defects (eles-2635)
- Sound waves vibrations are detected by the ear (eles-2636)

Interactivity
- Labelling parts of a human ear (int-8176)

Weblink
- The human eye

2.5 The brain

eWorkbooks
- Labelling the brain (ewbk-5111)
- The brain (ewbk-5113)

Practical investigation eLogbook
- Investigation 2.4: Dissection of a mammal's brain (elog-0633)

Video eLesson
- Willis and the brain (eles-1783)

Interactivity
- Labelling the human brain (int-8229)

Weblink
- Neuroscience

2.6 The endocrine system — slow control

eWorkbooks
- Labelling the endocrine system (ewbk-5115)
- Labelling the male reproductive system (ewbk-5117)
- Labelling the female reproductive system (ewbk-5119)
- The endocrine system (ewbk-5121)

Video eLessons
- Methods of contraception (eles-0127)
- The male endocrine system (eles-2633)

Interactivities
- Reproductive system (int-3032)
- Endocrine glands (int-5766)

2.7 Plant hormones

eWorkbook
- Different types of plant hormones (ewbk-5123)

Practical investigation eLogbooks
- Investigation 2.5: The effect of a commercial rooting powder on cutting development (elog-0635)
- Investigation 2.6: Plant responses to hormones (elog-0637)

Video eLesson
- Circadian rhythm (eles-2637)

2.8 Emotions and the limbic system

eWorkbooks
- Labelling the limbic system (ewbk-5125)
- The body continuum (ewbk-5127)

Video eLesson
- The hypothalamus (eles-2638)

2.9 Memory

Weblink
- Memory, attention and distraction

2.10 Sleep

Video eLesson
- During REM the eyes flick in different directions (eles-2640)

2.12 Damage to the nervous system

Weblinks
- Stem cells
- Fight MND

2.13 Studying the brain

Video eLesson
- An MRI scan (eles-4186)

2.14 Review

eWorkbooks
- Topic review Level 1 (ewbk-5133)
- Topic review Level 2 (ewbk-5135)
- Topic review Level 3 (ewbk-5137)
- Study checklist (ewbk-5139)
- Literacy builder (ewbk-5140)
- Crossword (ewbk-5142)
- Word search (ewbk-5144)
- Reflection (ewbk-3038)

Practical investigation eLogbook
- Topic 2 Practical investigation eLogbook (elog-0625)

Digital document
- Key terms glossary (doc-34973)

To access these online resources, log on to **www.jacplus.com.au**.

3 Systems working together

LEARNING SEQUENCE

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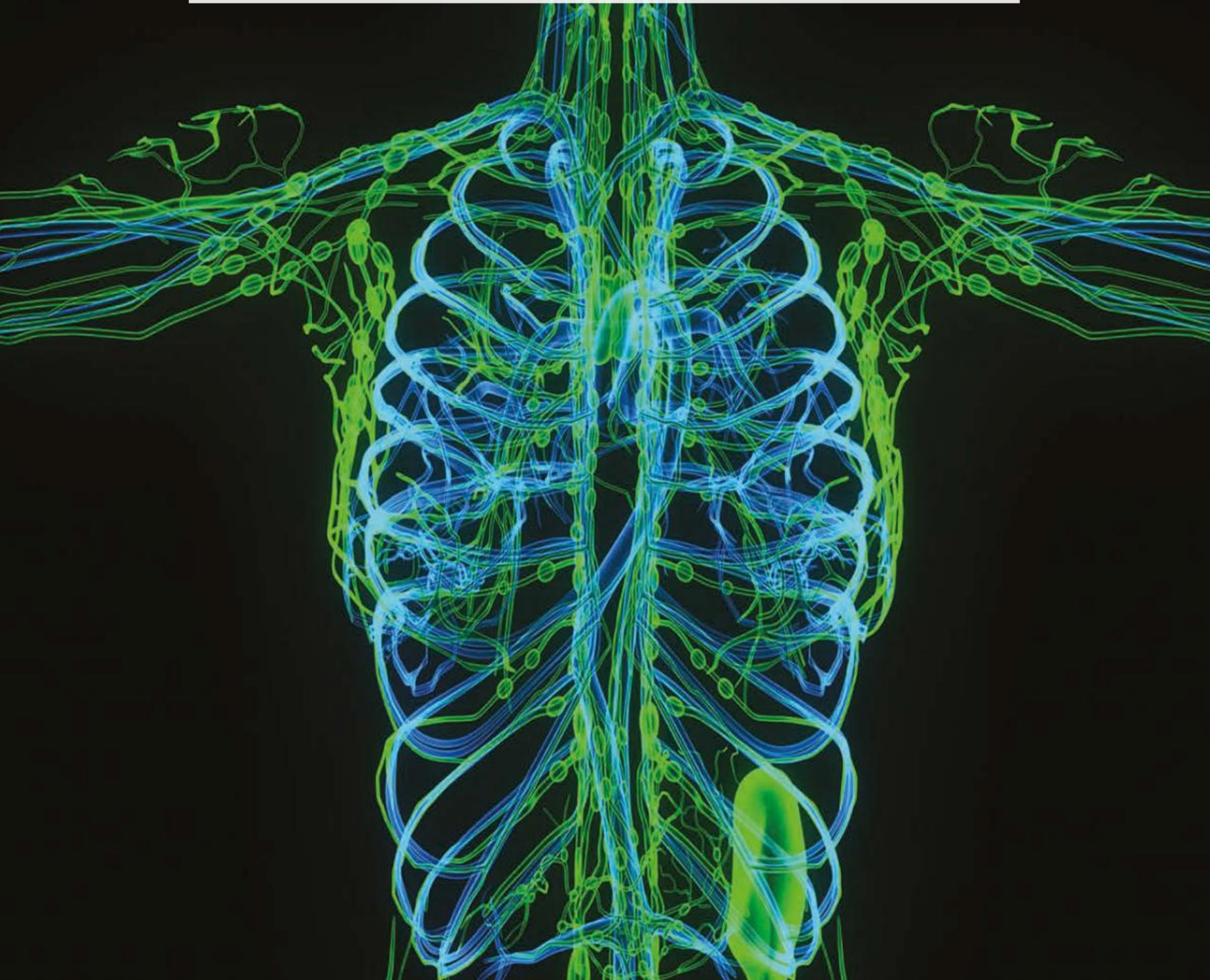


3.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

3.1.1 Introduction

Like those of other multicellular organisms, your body systems work together to keep you alive. Each body system is made up of organs with specific functions. An important function of your body systems is to supply your cells with energy and nutrients, and to remove wastes that are produced. To achieve this, your body systems do not work independently of each other — they work together. This requires organisation, coordination and control.

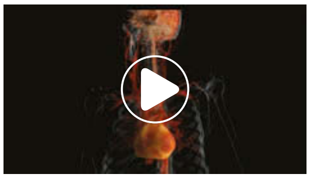
FIGURE 3.1 Athletes rely on body systems that work in a coordinated manner. They need to have a supply of energy to keep them healthy and strong.

The nervous and endocrine systems were discussed in topic 2. This topic will focus on the interdependence of the circulatory system and respiratory system, and the digestive system and excretory system. The respiratory system allows gas exchange between cells and your environment; the circulatory system moves substances around and between body systems; the digestive system breaks down food and absorbs nutrients; and the excretory system helps the body to get rid of wastes from metabolism.

on Resources

Video eLesson Body systems animation (eles-4171)

Watch this short animation demonstrating some of the major systems in the human body. How many systems and organs can you recognise?



3.1.2 Think about body systems

1. Is it the amount of oxygen or carbon dioxide in your blood that influences your breathing rate?
2. Does breathing rate differ at sea level or high in the mountains?
3. In what form are old red blood cells excreted in faeces?
4. Which vitamin deficiency may result in poor blood clotting?
5. What's wrong with glucose in your urine?
6. Does eating food stop you from getting drunk?
7. What's the link between cocaine and neurotransmitters in the brain?
8. Which is better, high or low GI?
9. Is chicken soup good for fevers?
10. Should the government be able to control what and how much you eat and drink?

3.1.3 Science inquiry

Design an organism

Have you ever wondered what the recipe for life is? Which ingredients would you blend together to make up a living thing? How could this mixture result in life?

Scientists have developed a whole range of different instruments and technologies to discover more about life processes. This has helped develop our knowledge and understanding of the structure of living things and how they work. Investigations provide us with more information about chemical processes that occur in cells and keep living things alive.

1. a. Identify an environment in which your organism will live.
   b. Describe the temperature, light intensity, water availability, food sources and other factors that you consider to be important to the survival of your organism.
2. Design your organism.
   a. Identify how your organism:
      i. obtains nutrients
      ii. obtains oxygen
      iii. removes its wastes.
   b. Identify how nutrients, oxygen and its wastes are transported within its body.
   c. Identify how the organism senses and responds to its environment.
3. Draw labelled diagrams of your organism's cells, tissues, organs and systems. Remember to take the function of each of these into account when you are designing its structure.
4. Describe how each of your organism's systems work together to keep it alive.
5. Construct a model of your organism.
6. Construct an electronic or hard-copy brochure that advertises what a magnificent life form your organism is. Think about who you are advertising your organism to. Is your target audience a zoo or a documentary film-maker or someone else?

FIGURE 3.2 *Grimpoteuthis*, one of the 15 species of umbrella (or dumbo) octopuses — they live in the deep sea in very cold water and without sunlight.

FIGURE 3.3 Tardigrades are half-a-millimetre-long water animals that have been found in rainforests, the Antarctic, in mud volcanoes and in the deep sea.

on Resources

eWorkbooks	Topic 3 eWorkbook (ewbk-4759) Student learning matrix (ewbk-4758) Starter activity (ewbk-4761)
Practical investigation eLogbook	Topic 3 Practical investigation eLogbook (elog-0546)
learnon	Access and answer an online Pre-test and receive **immediate corrective feedback** and **fully worked solutions** for all questions.

3.2 Respiratory and circulatory systems

LEARNING INTENTION

At the end of this subtopic you will understand how the respiratory and circulatory systems work together to supply oxygen to your cells and remove carbon dioxide from them.

3.2.1 The respiratory system and the circulatory system

The respiratory system

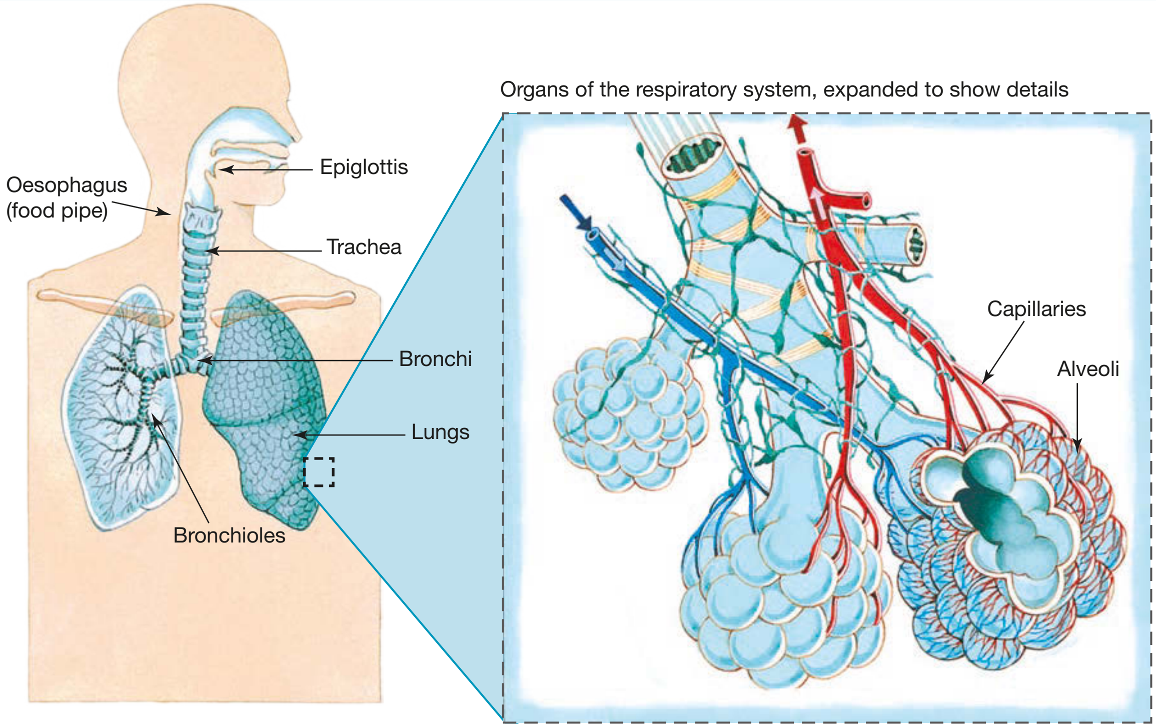
The **respiratory system** is responsible for getting oxygen into your body and carbon dioxide out. This occurs when you inhale (breath in) and exhale (breathe out). The main organ in this system is the **lungs**. It is in the alveoli of the lungs that gas exchange occurs (figure 3.4).

ewbk-4763

eles-2642

int-8233

FIGURE 3.4 The human respiratory system



respiratory system the body system that includes the lungs and associated structures and is responsible for the gas exchange of getting oxygen into your body and carbon dioxide out

lungs the organ for breathing air. Gas exchange occurs in the lungs.

The circulatory system

The **circulatory system**, also called the cardiovascular system, is responsible for transporting oxygen and nutrients to your body's cells, and wastes such as carbon dioxide away from them. This involves blood cells that are transported in your blood vessels (arteries, veins, and capillaries) and your heart. Arteries transport blood to the heart and veins transport blood back to the heart. Arteries are narrower than veins, which means blood is under higher pressure in the arteries than in the veins. Capillaries are the site at which exchange of materials with the cells occurs.

circulatory system the body system that includes the heart, blood and blood vessels and is responsible for circulating oxygen and nutrients to your body cells and carbon dioxide and other wastes away from them

The heart is actually two pumps. One side pumps oxygenated blood and the other pumps deoxygenated blood (figure 3.6).

FIGURE 3.5 Heart and blood vessel flow chart

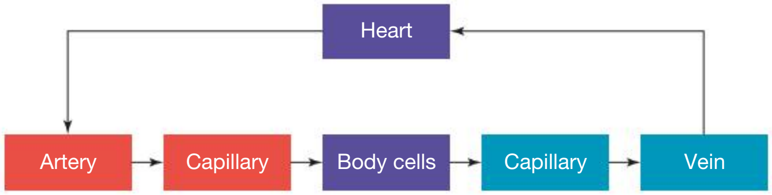
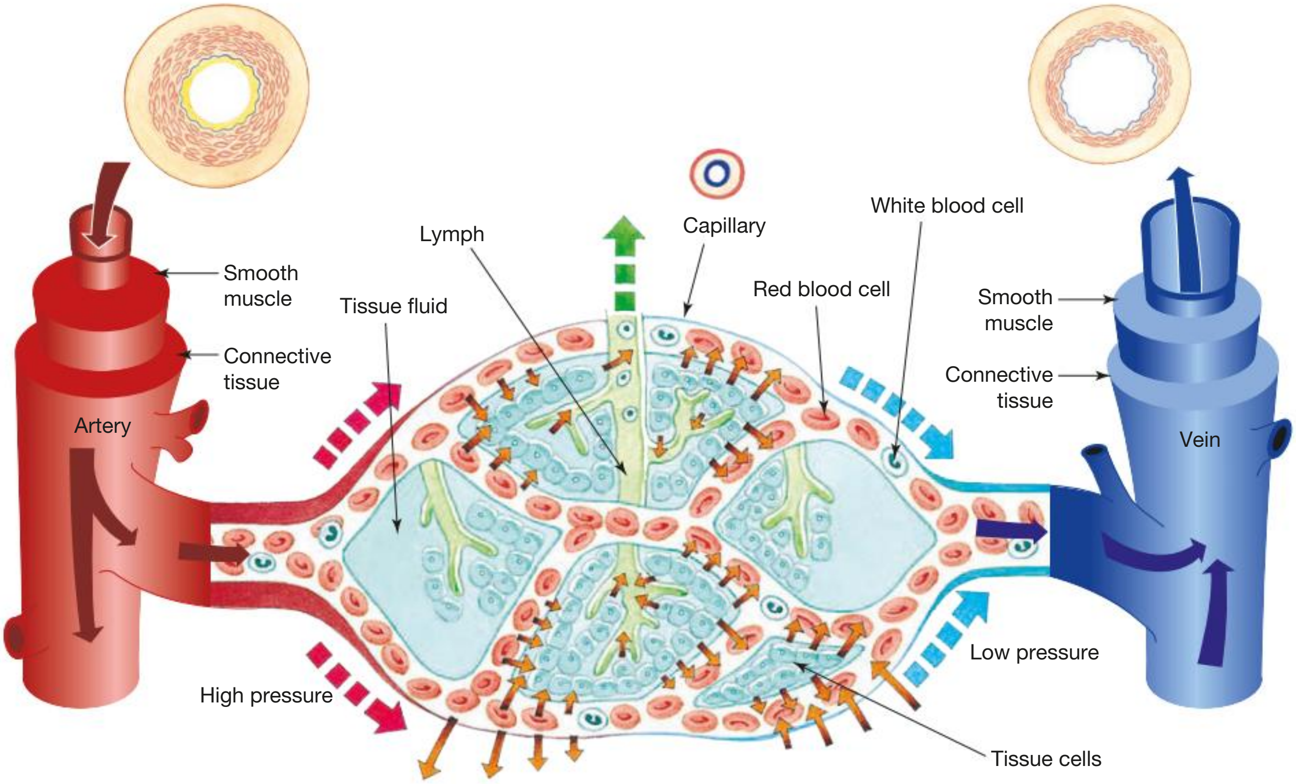


FIGURE 3.6 The oxygenated blood coming from the artery (red) moves into the finer capillaries where the thin walls allow an exchange of gases into the tissues. Carbon dioxide is released from the tissues to the blood stream where the veins take the deoxygenated blood (blue) back to the heart and lungs.



3.2.2 Cells need energy!

Your circulatory and respiratory systems work together to provide your cells with **oxygen**, which is essential for the process of making energy. This process is called cellular respiration. It involves the breaking down of **glucose** so that energy is released and can be converted into a form that your cells can use. As can be seen in the cellular respiration equation below, **carbon dioxide** is produced as a waste product. The carbon dioxide then needs to be removed from your cells or it would result in their damage or death.

Cellular respiration

Cellular respiration is the breakdown of food (glucose) in the presence of oxygen, which releases energy that can be transformed into a form that cells can use. Carbon dioxide is a waste product.

$$\text{Glucose} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water} + \text{energy}$$

EXTENSION: Details of cellular respiration

Cellular respiration actually occurs through a complex series of biochemical equations. It can be simplified as follows:

$$\begin{array}{ccccccccc} C_6H_{12}O_6 & + & 6O_2 & \rightarrow & CO_2 & + & H_2O & + & (\text{ATP}) \\ \text{Glucose} & + & \text{oxygen} & \rightarrow & \text{carbon dioxide} & + & \text{water} & + & \text{energy (ATP)} \end{array}$$

As this series of reactions give out energy, they are known as exergonic reactions, and the energy released is used to produce a useable form of energy known as ATP.

3.2.3 Transport in the respiratory and circulatory systems

Transport through your circulatory system

Your circulatory system is responsible for:

- transporting oxygen and nutrients to your body's cells
- transporting wastes such as carbon dioxide away from your body's cells.

This involves blood cells that are transported in your blood vessels and heart. The three major types of blood vessels are:

- **arteries** — transport blood from the heart
- **capillaries** — where materials are exchanged with cells
- **veins** — transport blood back to the heart (as shown below).

oxygen tasteless and colourless gas in which molecules (0_2) are made up of two oxygen atoms. It is essential for cellular respiration for most organisms and is a product of photosynthesis.

glucose a six-carbon sugar (monosaccharide) that acts as a primary energy supply for many organisms

carbon dioxide a colourless gas in which molecules (CO_2) are made up of one carbon and two oxygen atoms; essential for photosynthesis and a waste product of cellular respiration. The burning of fossil fuels also

arteries hollow tubes (vessels) with thick walls carrying blood pumped from the heart to other body parts

capillaries minute tubes carrying blood to body cells. Every cell of the body is supplied with blood through capillaries.

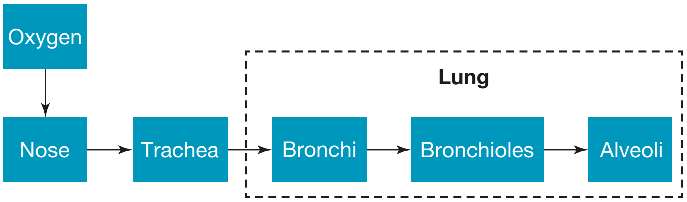
veins blood vessels that carry blood back to the heart. They have valves and thinner walls than arteries.

Inhaling: To get oxygen into your respiratory system

Your respiratory system is responsible for getting oxygen into your body and carbon dioxide out. This occurs when you inhale (breathe in) and exhale (breathe out).

To get oxygen into your respiratory system, you breathe in, but you actually take in a mixture of gases (of which about 21 per cent is oxygen) from the air around you. The air moves down your **trachea** (or windpipe), then down into one of two narrower tubes called **bronchi** (bronchus), then into smaller branching tubes called **bronchioles,** which end in tiny air sacs called **alveoli** (alveolus).

FIGURE 3.7 Flow chart of the human respiratory system



Getting oxygen into your circulatory system

Your alveoli are surrounded by a network of capillaries. The alveolus wall and capillary walls are each one cell thick, the minimum possible for oxygen and carbon dioxide to cross by diffusion. These capillaries contain **red blood cells** (or **erythrocytes**) that contain **haemoglobin**, an iron-based pigment that gives your blood its red colour. Oxygen moves from the alveoli into the red blood cells in the surrounding capillaries and binds to the haemoglobin to form oxyhaemoglobin. It is in this form that the oxygen is transported to your body cells.

trachea narrow tube from the mouth to the lungs through which air moves

bronchi the narrow tubes through which air passes from the trachea to the smaller bronchioles and alveoli in the respiratory system. Singular = bronchus.

bronchioles small branching tubes in the lungs leading from the two larger bronchi to the alveoli

alveoli tiny air sacs in the lungs at the ends of the narrowest tubes. Oxygen moves from alveoli into the surrounding blood vessels, in exchange for carbon dioxide. Singular = alveolus

red blood cells living cells in the blood that transport oxygen to all other living cells in the body. Oxygen is carried by the red pigment haemoglobin.

erythrocytes red blood cells

haemoglobin the red pigment in red blood cells that carries oxygen

FIGURE 3.8 Flow chart of oxygen moving into the circulatory system

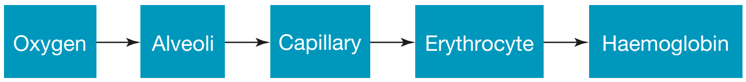
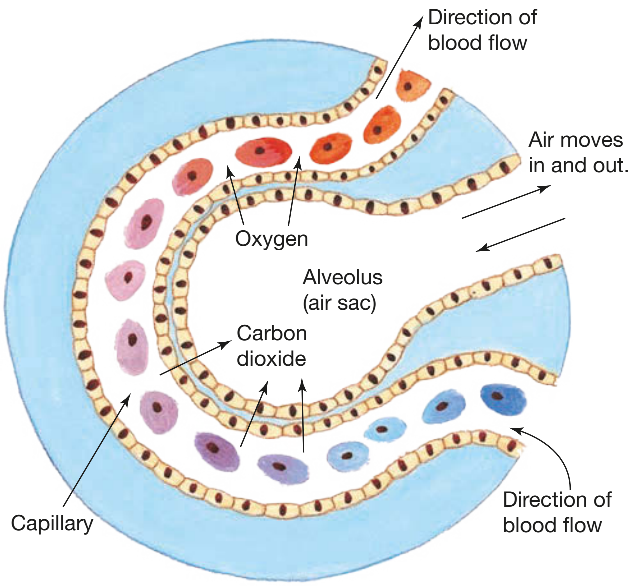


FIGURE 3.9 In an alveolus, oxygen diffuses into the blood and carbon dioxide diffuses out of the blood.



Transporting oxygen to your cells

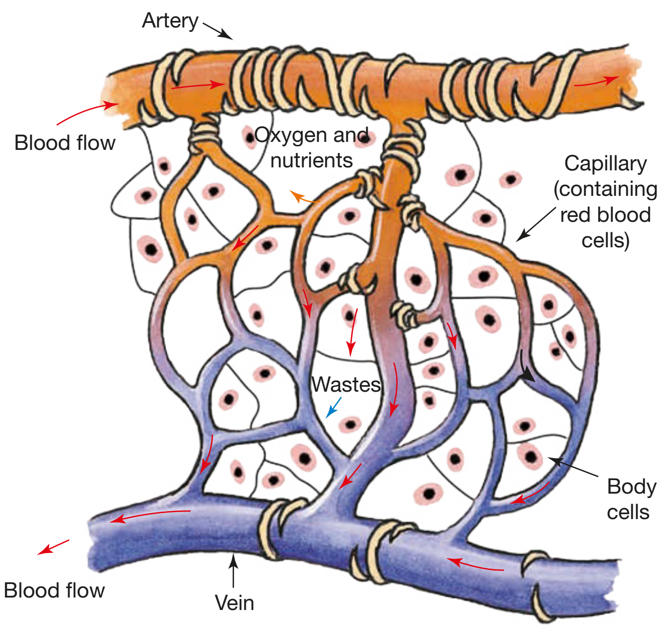
Oxygenated blood travels in a path, as shown in figures 3.10 and 3.12. It travels from your lungs via the **pulmonary vein** to the **left atrium** of your **heart**. From here, it travels to the **left ventricle** where it is pumped under high pressure to your body through a large artery called the **aorta**.

The arteries transport the oxygenated blood to smaller vessels called **arterioles** and finally to capillaries through which oxygen finally diffuses into body cells for use in cellular respiration (figure 3.11).

FIGURE 3.10 Flow chart of oxygen moving through the circulatory system to the body's cells

Oxygenated blood
↓
Pulmonary vein → Left atrium of heart → Left ventricle of heart → Aorta → Arterioles → Capillary → Body cell

FIGURE 3.11 In the capillaries, oxygen diffuses out of the blood and waste produced by cells diffuses into the bloodstream.



pulmonary vein the vessel through which oxygenated blood travels from your lungs to the heart

left atrium upper left section of the heart where oxygenated blood from the lungs enters the heart

heart a muscular organ that pumps blood through the circulatory system so that oxygen and nutrients can be transported to the body's cells and wastes can be transported away

left ventricle lower left section of the heart, which pumps oxygenated blood to all parts of the body

aorta a large artery through which oxygenated blood is pumped at high pressure from the left ventricle of your heart to your body

arterioles vessels that transport oxygenated blood from the arteries to the capillaries

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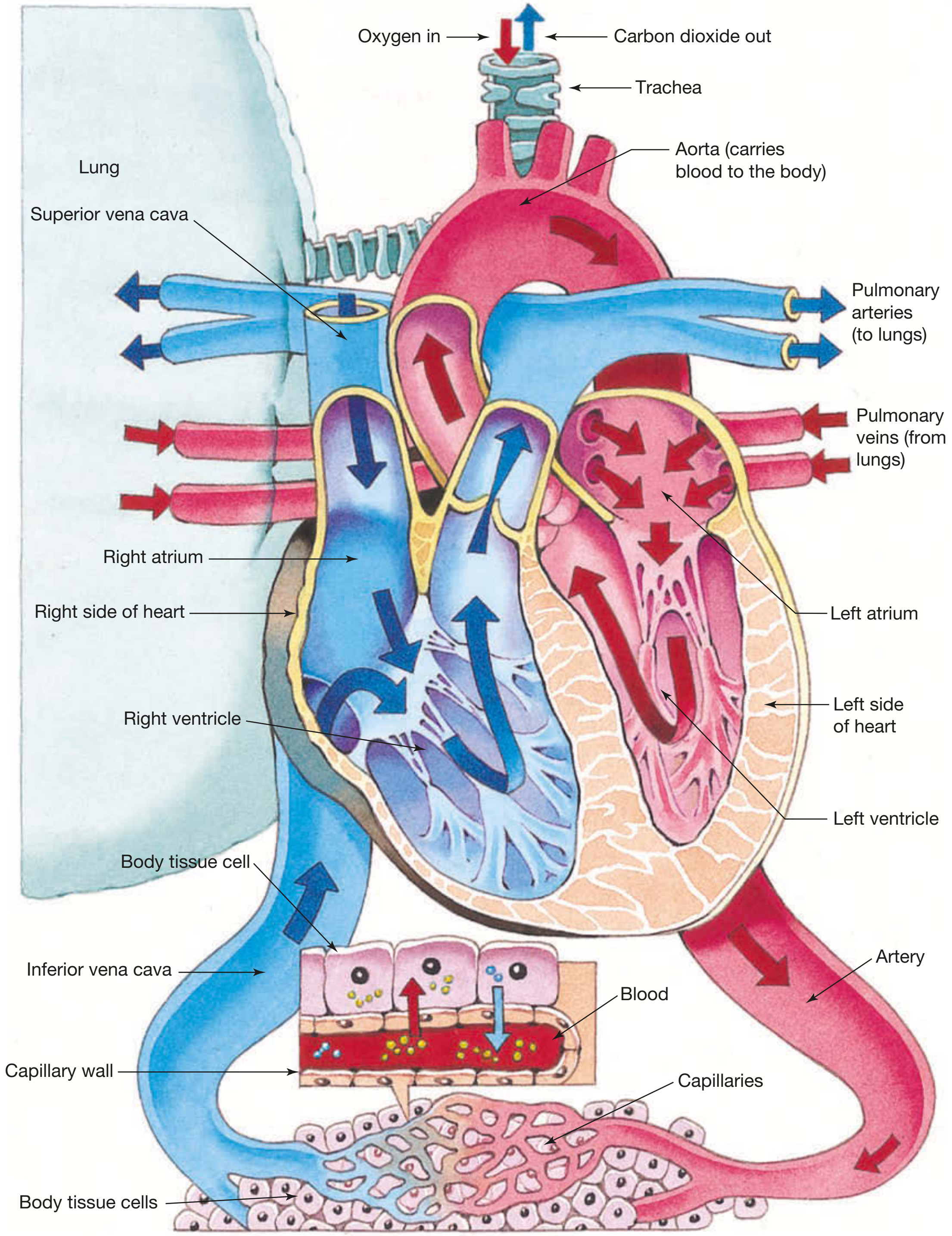
int-0210

FIGURE 3.12 The path of oxygenated (red) and deoxygenated (blue) blood through the heart

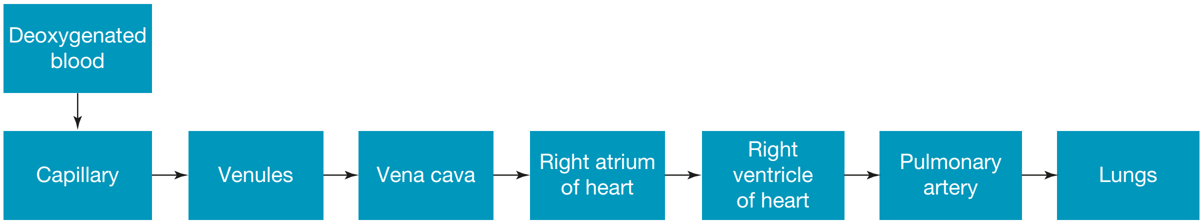


Transporting carbon dioxide away from your cells

When oxygen has diffused into the cell and the waste product of cellular respiration, carbon dioxide, has diffused out of the cell into the capillary, the blood in the capillary is referred to as **deoxygenated blood**.

The waste-carrying deoxygenated blood travels in a path (figures 3.12 and 3.13). It is transported via capillaries to **venules** (small veins) to large veins called **vena cava**, then to the **right atrium** of your heart. From here it travels to the **right ventricle** where it is pumped to your lungs through the **pulmonary artery**, so called because it is associated with your lungs. The pulmonary artery is the only artery that does not contain oxygenated blood.

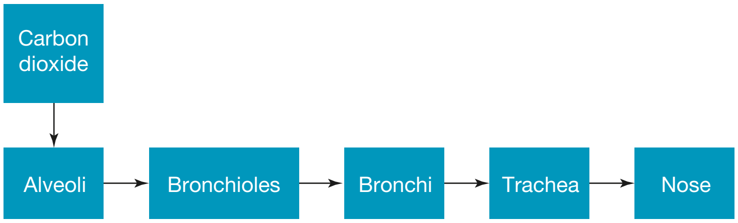
FIGURE 3.13 Flow chart of deoxygenated blood moving back to the lungs



Exhaling: to remove carbon dioxide from your respiratory system

To get rid of the carbon dioxide (CO_2) from the deoxygenated blood, your body needs to get carbon dioxide into your respiratory system and out of your body. Carbon dioxide in your capillaries diffuses into the alveoli in your lungs. It is then transported into your bronchioles, then your bronchi, and then into your trachea. From here, carbon dioxide is exhaled through your nose (or mouth) when you breathe out (figure 3.14).

FIGURE 3.14 Flow chart of carbon dioxide being released from the body



3.2.4 Working together

The respiratory system and the circulatory system work together to keep your cells alive. They achieve this by providing your cells with the oxygen required for cellular respiration and by removing its waste product carbon dioxide. In this subtopic you have followed the different pathways for the transport of oxygenated and deoxygenated blood through blood vessels and the heart. You have also seen where and how the exchange of oxygen and carbon dioxide occurs between the cells within the body, capillaries, and the alveoli of the lungs.

deoxygenated blood blood from which some oxygen has been removed

venules small veins

vena cava large vein leading into the top right chamber of the heart

right atrium upper right section of the heart where deoxygenated blood from the body enters

right ventricle lower right section of the heart, which pumps deoxygenated blood to the lungs

pulmonary artery the vessel through which deoxygenated blood, carrying wastes from respiration, travels from the heart to the lungs

FIGURE 3.15 The respiratory and circulatory system work together

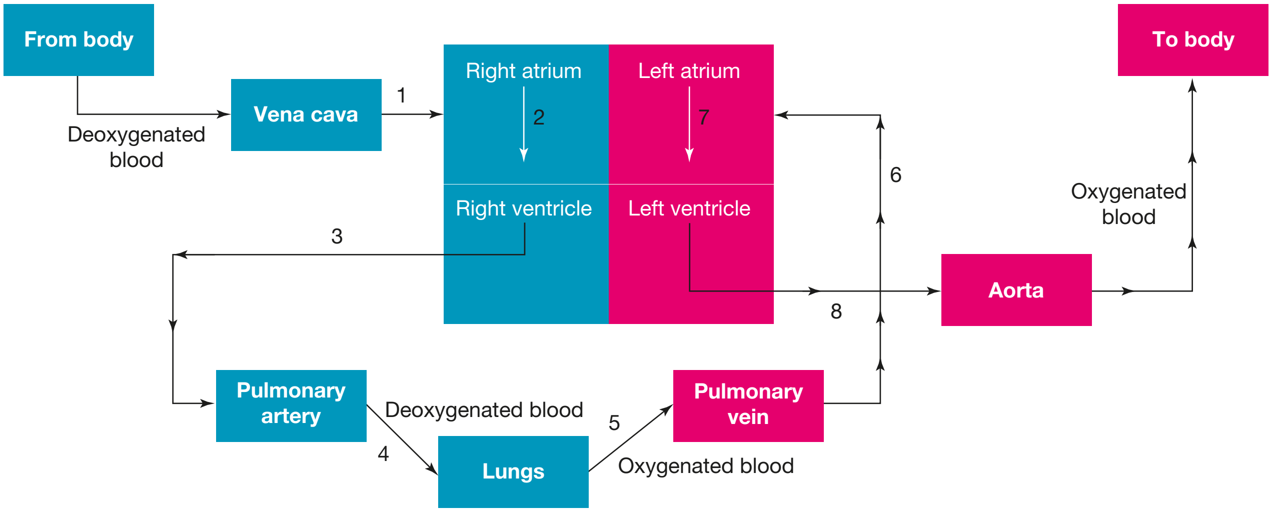
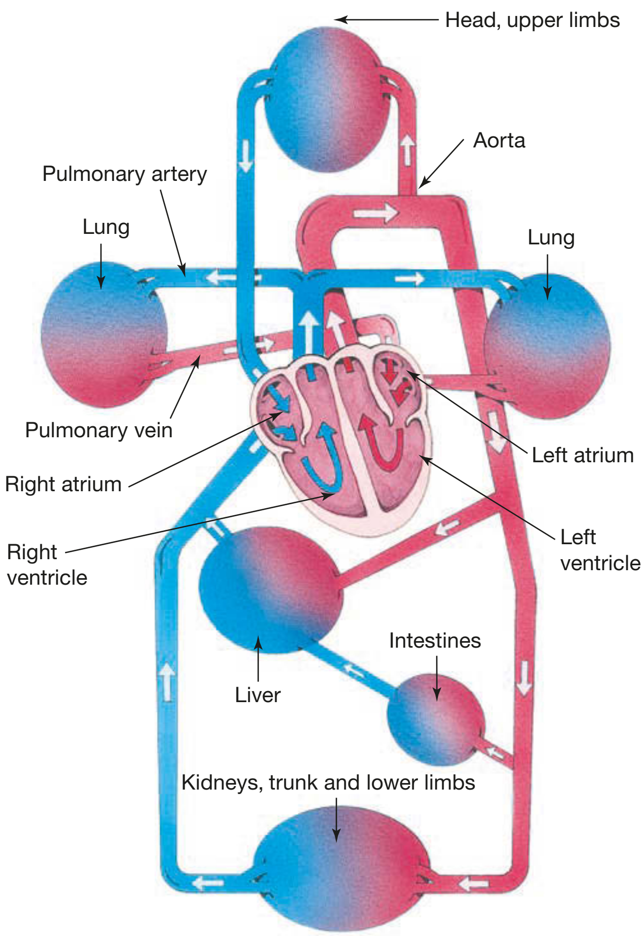


FIGURE 3.16 Connected highways — the routes for blood circulations



on Resources

assess on Additional automatically marked question sets

3.2 Exercise

learn on

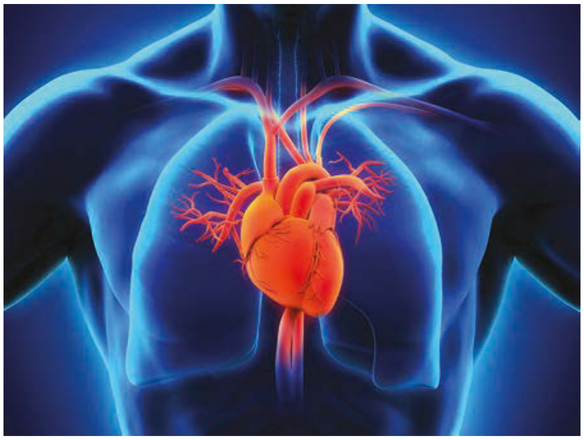
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Fill in the blanks, using the following words: alveoli, bronchi, bronchioles, trachea.
   When you breathe in, air moves down your _________then through the _________then through _________to tiny air sacs called _________.
2. Fill in the blanks to complete the sentences.
   The process of cellular respiration requires _________ and glucose, and produces energy in a form that the cell can use and _________ as a waste product.
3. State the word equation for cellular respiration.
4. Identify the molecule that the respiratory system and circulatory system work together to:
   a. supply to your cells
   b. remove from your cells.
5. a. MC Identify the name given to the blood vessel that takes oxygenated blood from the lungs to the left atrium of your heart.



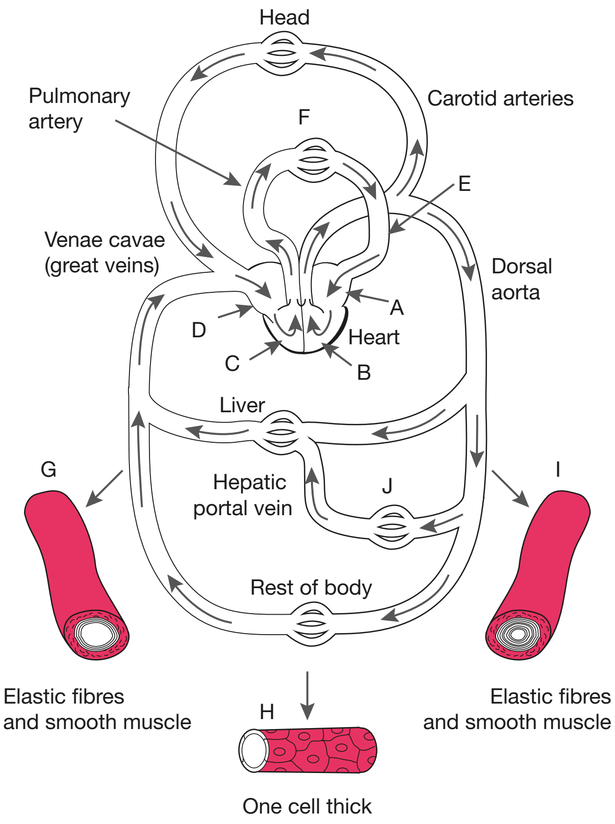
   A. Pulmonary artery B. Pulmonary vein C. Aorta D. Vena cava

   b. MC Identify the name given to the blood vessel that takes deoxygenated blood from the right ventricle of your heart to your lungs.
   A. Pulmonary artery B. Pulmonary vein C. Aorta D. Vena cava
6. Place the following sequence in order to show the pathway carbon dioxide travels from your body cells to your lungs:
   a. Body cell b. Capillary c. Pulmonary artery d. Right atrium
   e. Right ventricle f. Vena cava g. Venules h. Lungs

7. Identify which of the following statements are true and which are false. Justify any false response.
   a. Oxygen is a product of cellular respiration.
   b. Arteries have thicker, more muscular walls than veins.
   c. Blood travels to the heart in arteries.
   d. Blood in the aorta is oxygenated.
   e. Deoxygenated blood travels from your heart to your lungs in your pulmonary vein.

Apply and analyse

8. Label the lettered parts (A–J) in the figure.



9. **SIS** Construct a flow chart to show how oxygen travels through the body.
10. **SIS** Construct a flow chart to show how deoxygenated blood travels from body cells to the lungs.
11. **SIS** Construct a flow chart to show how carbon dioxide travels from the lungs to be exhaled through the nose.

Evaluate and create

12. Use Venn diagrams to compare:
    a. the right atrium and left atrium of the heart
    b. the right ventricle and left ventricle of the heart
    c. the left atrium and left ventricle of the heart
    d. oxygenated blood and deoxygenated blood.
13. Use Venn diagrams to compare:
    a. arteries and veins
    b. oxygen and carbon dioxide
    c. the pulmonary artery and pulmonary vein
    d. the aorta and vena cava.

Fully worked solutions and sample responses are available in your digital formats.

3.3 Essential intake

LEARNING INTENTION

At the end of this subtopic you will understand the differences between essential nutrients and non-nutrients and how they can affect our physical and mental health.

3.3.1 Essential nutrients

Feeling hungry? Tummy rumbling? You need to eat to provide your body with nutrients.

Nutrients are substances needed for energy, cell functioning and for your body's growth and repair. The five main groups of nutrients that your body needs to stay alive are:

- carbohydrates — provide a source of energy; found in grains, starchy vegetables and bread
- proteins — used for cell growth and repair of damaged tissues, and produce enzymes and hormones; found in meat, poultry, eggs, legumes and nuts
- lipids — a source of energy found in oils and fats
- vitamins and minerals — needed in small amounts and speed up and control chemical reactions in the body; found in numerous foods, especially fruits and vegetables.

All of these except minerals are called organic nutrients because they contain carbon, hydrogen and oxygen.

FIGURE 3.17 Nutrients are needed for energy, cell functioning and body growth and repair.

CASE STUDY: Feeding your emotions

Your body also needs the raw materials from nutrients to make **neurotransmitters** that can affect your emotions. For example, dopamine and norepinephrine are made up of three amino acids. These are:

- tryptophan — from food sources such as cottage cheese, peanuts, red meat and brown rice
- tyrosine — from foods such as almonds, avocados, bananas and dairy products
- phenylalanine — from meat, fish, eggs and soy products.

Tryptophan is also important in the synthesis of another neurotransmitter called serotonin. For more information on these neurotransmitters see section 3.7.1.

neurotransmitters signalling molecules released from the axon terminals into the synapse between nerve cells (neurons)

Small but important

Even though **vitamins** and **minerals** are required in only small amounts, they are very important to your health. Your **endocrine system** and **nervous system** also require a number of these to be able to effectively function and maintain a healthy environment for your cells.

Vitamin-deficiency diseases can be caused by lack of a particular vitamin. Diseases such as scurvy, rickets and beriberi have become less common as people have become more aware of the importance of vitamins. Deficiencies of minerals can also cause a number of significant problems.

vitamins organic nutrients required in small amounts. They include vitamins A, B, C, D and K.

minerals any of the inorganic elements that are essential to the functioning of the human body and are obtained from foods

endocrine system the body system composed of different glands that secrete signalling molecules (hormones) that travel in the blood for internal communication and regulation and to maintain homeostasis

nervous system he body system in which messages are sent as electrical impulses (along neurons) and chemical signals (neurotransmitters across synapses)

vitamin-deficiency diseases diseases caused by a lack of any vitamins in the diet

FIGURE 3.18 Mind-mapping your essential nutrients

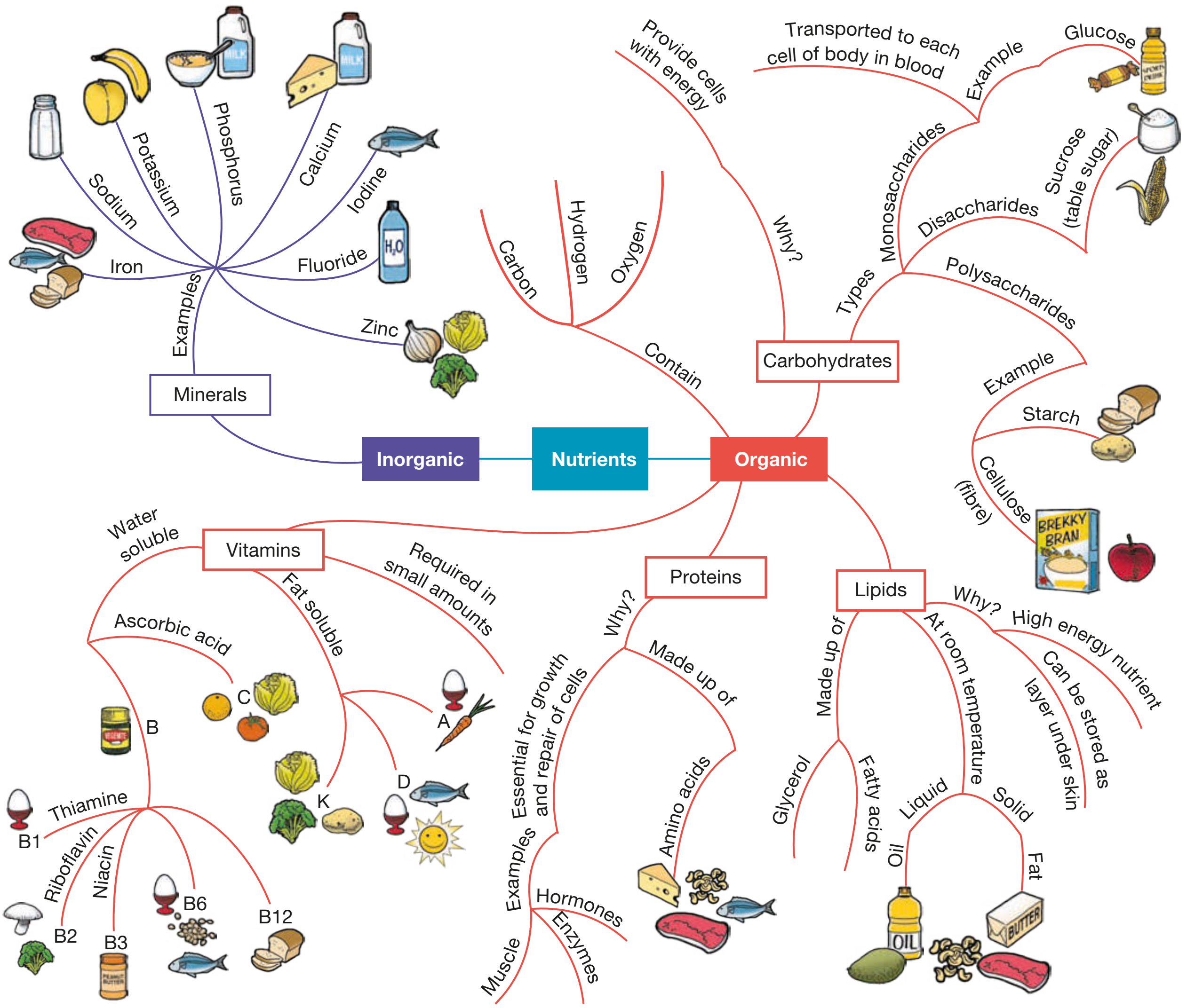


FIGURE 3.19 Vitamins and minerals needed for the body to function

EXTENSION: Making predictions about vitamin D

Vitamin D is important for strong bones and muscles because it controls calcium levels in the blood. While we typically gain our vitamins from the food we eat, our main source for vitamin D is from ultraviolet (UV) radiation from the Sun. However, the Sun's UV radiation is also the main cause of skin cancer.

a. Do you think people with naturally darker skin (skin with a higher melanin content) are at higher or lower risk of developing a vitamin D deficiency?

b. Does scientific research support your opinion? Research and record relevant information, citing your references.

c. Pose three questions that could be used to guide further research.

FIGURE 3.20 Sunlight is the main source of vitamin D.

3.3.2 Essential non-nutrients

Foods contain other important substances that are not nutrients. They are not used for energy or for growth and repair, but they are still essential to your health. Two of these substances are water and fibre.

Water

Did you realise that about two-thirds of your body is water? Water is another essential substance that you need to stay alive.

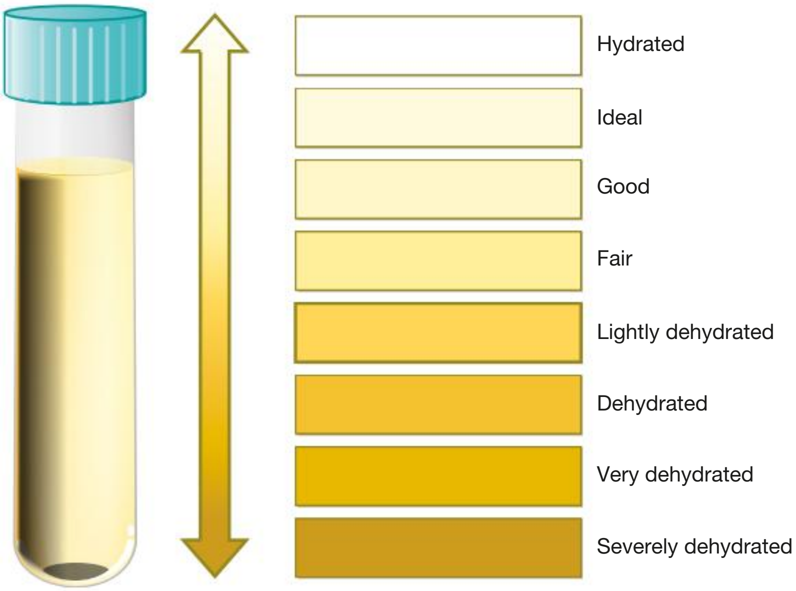
- Many of the chemical reactions that take place inside you use water.
- Your blood is 90 per cent water — the fluid part (plasma) is mostly water. Blood helps carry nutrients within and between the cells of the body.
- Water is necessary for the excretory system as it helps the kidneys do their job because it dilutes toxic substances and absorbs waste products so they may be transported out of the body.

You may be able to survive 40 days without food, but no more than 3 days without water.

How much water have you drunk today? Each day you lose water when breathing out (0.5 litres), sweating (0.5 litres) and urinating (1.5 litres). Have you replaced water that you have lost today? If you lose too much water, you may become **dehydrated**. A dry throat and mouth and dark-coloured urine are signs of mild dehydration. Figure 3.21 shows various colour changes in urine. The first three shades show a hydrated body. If you lose more than 20 per cent of your body's water volume, you could die!

dehydrated state in which too much water has been lost from the body

FIGURE 3.21 Urine colour is a good indication of dehydration.



If you drink a lot of water, more will be absorbed from your large intestine, and the kidneys will produce a greater volume of dilute urine. If you do not consume enough liquid you will urinate less and produce more concentrated urine.

DISCUSSION

Melbourne has had fluoride added to their drinking water since 1977. It is at a level to help prevent tooth decay as it strengthens the tooth's enamel. However, this addition of fluoride to our water supplies has caused much controversy. Why do you think this topic was and still is controversial? Do we need fluoride in our water if we consider all modern toothpastes contain fluoride anyway?

Fibre

Fibre is found in the walls of plant cells, such as fruits, vegetables, wholegrain breads and cereals, nuts and seeds and is only partially broken down by your digestive system. Although it really does go 'in one end and out the other', it serves a very useful purpose and is an essential part of your diet by providing bulk to your food, allowing it to move properly through your intestines.

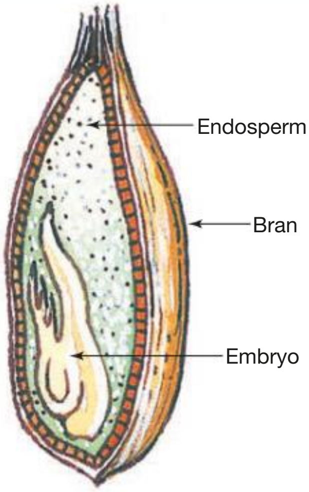
Without fibre, undigested food travels too slowly through the large intestine, losing too much water. The result is difficulty in releasing the solid food waste from the body, a condition called **constipation**. Lack of fibre in the diet can also lead to haemorrhoids (varicose veins around the anal passage, also known as piles), bowel cancer and several other diseases.

Wholegrain products are higher in dietary fibre because they contain the outer covering, or bran, of the grain (figure 3.23). When grains are highly processed, as they are in the production of white bread, white flour and many breakfast cereals, the bran is removed so they have less fibre in them.

constipation a condition of the bowels, caused by lack of dietary fibre, in which solid wastes cannot easily leave

FIGURE 3.22 These foods contain fibre.

FIGURE 3.23 A grain of wheat



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INVESTIGATION 3.1

Essential testing

Aim

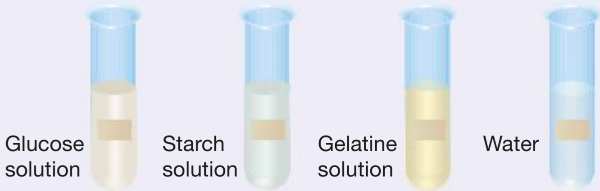
To investigate the nutrients found in foods

Materials

- test-tube rack
- 4 test tubes
- safety glasses
- glucose solution
- starch solution
- gelatine solution
- distilled water
- iodine solution
- test-tube holder
- Benedict's solution
- tongs
- candle or Bunsen burner
- matches
- heatproof mat
- 0.01 M copper sulfate solution
- 1.00 M sodium hydroxide solution
- food samples such as potatoes, bread, cheese, milk, pasta, egg white, apple, onion, spinach

Method

1. From your kitchen cupboards, select five foods to test. If they are solid, you may need to use a mortar and pestle to grind them into a 'mash' with a small amount of water before testing.
2. Predict which of your food samples will contain starch, glucose and/or protein.
3. Create standards.
   For each of the tests in this experiment, set up the four test tubes as shown below. After each test, clean the test tubes by rinsing with water. Make sure a fresh sample of each liquid is used for each test.

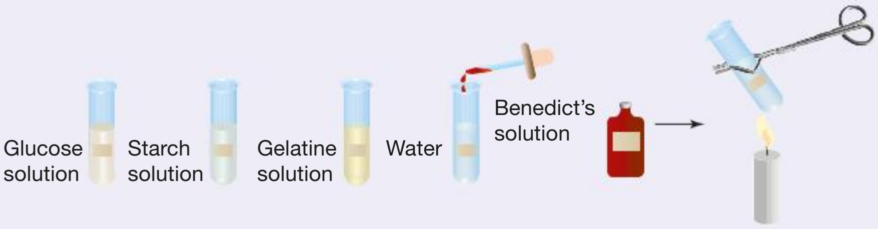


Test A: Starch test

4. Add two drops of iodine solution to each of the four test tubes. Observe any colour change and record the results.

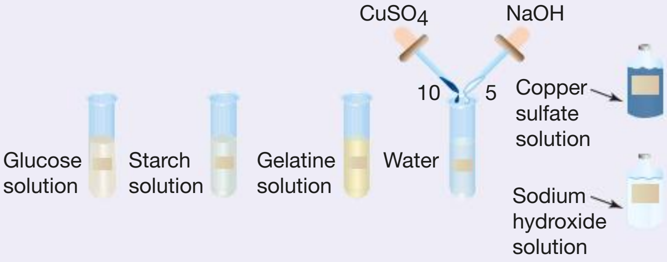
Test B: Glucose test

5. Add four drops of Benedict's solution to each of the four test tubes. Gently heat each test tube over a Bunsen burner flame. Observe any colour change and record the results.



Test C: Protein test

6. Add ten drops of copper sulfate solution to each of the four test tubes. Then add five drops of sodium hydroxide solution to each test tube. Observe any colour change and record the results.



EXTENSION: Essential food tests

7. Using the three tests above, investigate the food samples for the presence of starch, glucose and protein. (*Note*: Add *only* your food samples to these tests, *not* the glucose, starch or gelatine solutions.)

Results

Record the test results.

TABLE Results of investigation 3.1

Test results	Water	Glucose solution	Starch solution	Gelatine solution
Test A: Starch test				
Test B: Glucose test				
Test C: Protein test				

Discussion

1. Suggest why you set up standard tests and added the same volumes of solutions to each test tube.
2. Which foods contain two or more of the nutrients tested for?
3. Were your predictions supported by your results?
4. Comment on your overall findings.
5. If you were to do the food testing again, suggest how you might improve the procedure.

Conclusion

What can you conclude about the nutrients in the foods you tested?

ACTIVITY: What's in your kitchen cupboard?

In this activity you will investigate the nutrients found in packaged foods of your choosing.

1. Find ten food items in your kitchen that have the nutrients listed on the packaging.
2. Draw up a table like the one shown to summarise your findings.

TABLE Nutritional content of food samples Nutrients

Name of food	Nutrients per 100 grams						
	Energy (kJ)	Protein (g)	Fat (g)	Total carbohydrate (g)	Sugar (g)	Dietary fibre (g)	Sodium (mg)
'Light'n 'tasty' cereal	1540	8.7	3.1	71.3	23.6	7.7	225
Potato chips	2130	8.5	31.9	45.1	1.8	3.0	518
Apricot jam	1140	6.4	0.1	66.6	59.4	–	17
Barbecue-flavoured 'shapes' biscuits	2184	10.2	25.2	63.3	1.4	–	752
Multigrain corn thins	380	9.5	3.0	77.6	0.7	8.5	201

Questions

1. Which of the foods was highest in:
   a. energy
   b. protein
   c. fibre
   d. sodium?
2. Rank the foods in order from highest to lowest for:
   a. fat
   b. fibre
   c. energy.
   Are your results what you expected? Why?
3. The recommended daily fibre intake is 30–40 g. On the basis of your findings, put together a meal of your packaged foods that would meet this requirement.
4. Draw a bar graph of your results for your foods and their fat content.
5. a. Compare your results with those of two other students.
   b. How were they similar and how were they different?
   c. Select foods from your group to put together a meal. Using the nutrient tables, calculate the amount of each nutrient in your designed meal.
6. a. Suggest three questions that you could research on the topics of nutrients or packaging labels.
   b. Collate the questions from the whole class and select one of these questions to research.
   c. Report your findings back to the class.

SCIENCE AS A HUMAN ENDEAVOUR: Careers in nutrition

Nutritionists and dietitians are two careers with a focus on nutrition. These careers may involve communication of nutrition messages to individuals or to various groups within the community. These careers may be in private, public or community health, in the food industry or in various types of research.

Clinical nutritionists may have face-to-face consultations and discussions with their clients about dietary changes that may be required. While clinical nutritionists approach issues from a 'nutrient' perspective, dietitians may be working in a hospital or private practice to advise their clients about food and lifestyle changes.

Dietitians provide advice to people diagnosed with diet-related diseases such as diabetes, coeliac disease, heart disease and certain types of cancers.

Dietitians may also be involved in determining the appropriate food solution for patients who require a drip or nasogastric tube (a tube that goes through the nose and down into the stomach).

on Resources

assesson Additional automatically marked question sets

3.3 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Give two reasons why you need to eat.
2. **MC** Identify which type of nutrient has a key role in providing the raw materials required for cell growth and repair of damaged and worn-out tissue.
   A. Carbohydrates **B.** Lipids **C.** Minerals **D.** Proteins
3. **MC** Identify which type of nutrient is associated with enzymes, hormones and muscles.
   A. Carbohydrates **B.** Minerals **C.** Proteins **D.** Vitamins
4. How do cells get the energy that they need?
5. **a.** What are proteins made of?
   b. Why are they important?
6. **a.** Explain why it is important to drink water.
   b. Describe the symptoms of dehydration.
7. **a.** What is fibre?
   b. Why is it important to eat fibre even though the chemicals in it are not used by your body?
8. Fill in the following table:

TABLE Source, importance and deficiency signs of vitamins

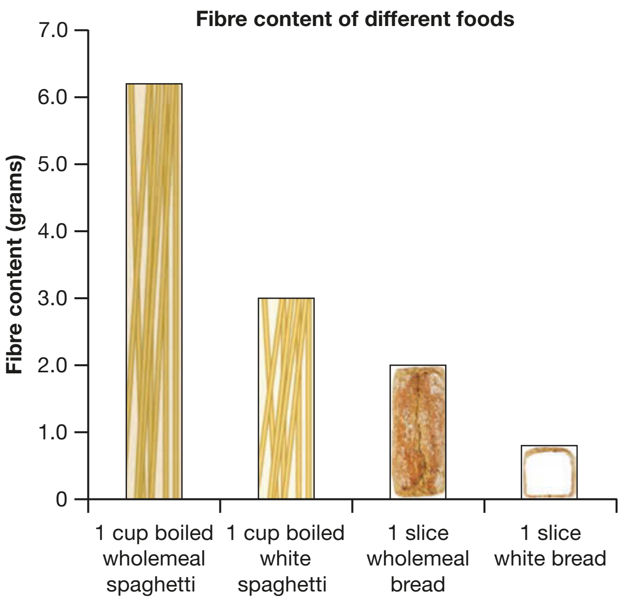
Nutrient	Foods found in	Importance	Deficiency signs
Vitamin A			
Vitamin C			
Vitamin D			
Vitamin K			
Calcium			
Iron			
Magnesium			
Zinc			

Apply and analyse

9. Suggest why pregnant women need more protein than other adults.
10. Milk and other dairy products are well known as good sources of calcium. Which nutrients would be missing from the diet of someone whose food intake consisted mainly of dairy products?
11. Identify shared features for the following pairs:
    a. carbohydrates and lipids **b.** cellulose and starch **c.** fats and oils
    d. iron and potassium **e.** hormones and enzymes.
12. **a.** Which amino acids are required for the synthesis of dopamine and norepinephrine? Name some foods that these are found in.
    b. Which amino acid is important for the synthesis of serotonin? Name some foods that it can be found in.

Evaluate and create

13. **SIS** The graph shows the fibre content of various foods.
    a. What do the results in the graph suggest?
    b. Find two foods in your pantry that have fibre content listed on their label. How does their fibre content compare to the graph examples?
    c. What is the difference between wholemeal and wholegrain?



14. A high-carbohydrate meal can increase your brain's tryptophan levels.
    a. What effect might this have on your mood?
    b. Which neurotransmitter(s) is/are likely to be involved?
    c. At what time of the day would it be a good idea to have such a meal? Why?
15. A high-protein meal can raise tyrosine levels in your blood and brain.
    a. What effect might this have on your mood?
    b. Which neurotransmitter(s) is/are likely to be involved?
    c. At which time of the day would it be a good idea to have such a meal? Why?
    d. If tyrosine is also needed to make active thyroid hormones, what may result if there are insufficient levels of this amino acid in your blood?

Fully worked solutions and sample responses are available in your digital formats.

3.4 Digestive and excretory systems

LEARNING INTENTION

At the end of this subtopic you will understand the importance of the digestive and excretory organs and how they are coordinated as interdependent systems for the health of our bodies.

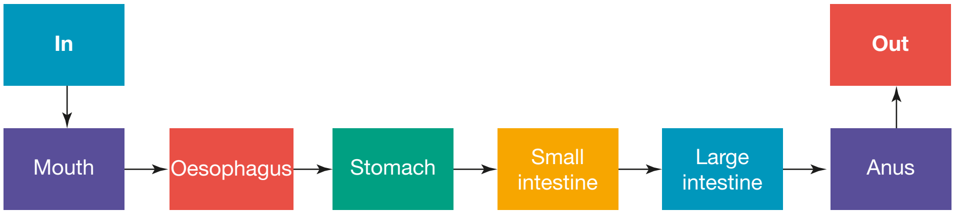
3.4.1 The digestive system — In we go!

The key role of your **digestive system** is to supply your body with the nutrients it requires to function effectively. It breaks down food into smaller particles, which are then absorbed into your tissues and cells. There are two types of digestion:

- **mechanical digestion** — the physical breakdown of food; it begins in the mouth as food is chewed
- **chemical digestion** — when food is broken down further into simpler compounds or nutrients used by cells.

The pathway of the digestive and excretory system is summarised in figure 3.24.

FIGURE 3.24 Flow chart of digestion and excretion



3.4.2 Digestive organs — Down we go!

Mouth

The whole process of **digestion** starts with you taking food into your mouth.

- Chemical digestion of some of the carbohydrates begin in your mouth with **enzymes** (such as amylases) in your **saliva**, which are secreted by your **salivary glands**.
- Mechanical digestion, uses your teeth to physically break down the food then your tongue rolls the food into a slimy, slippery ball-shape called a **bolus**.

digestive system a complex system of organs and glands that processes food in order to supply your body with the nutrients to cells so they can function effectively

mechanical digestion digestion that uses physical factors such as chewing with the teeth

chemical digestion the chemical reactions changing food into simpler substances that are absorbed into the bloodstream for use in other parts of the body

digestion breakdown of food into a form that can be used by an organism. It includes both mechanical digestion and chemical digestion.

enzymes special chemicals that speed up reactions but are themselves not used up in the reaction

saliva watery substance in the mouth that moistens food before swallowing and contains enzymes involved in the digestion of food

salivary glands glands in the mouth that produce saliva

bolus round, chewed-up ball of food made in the mouth that makes swallowing easier

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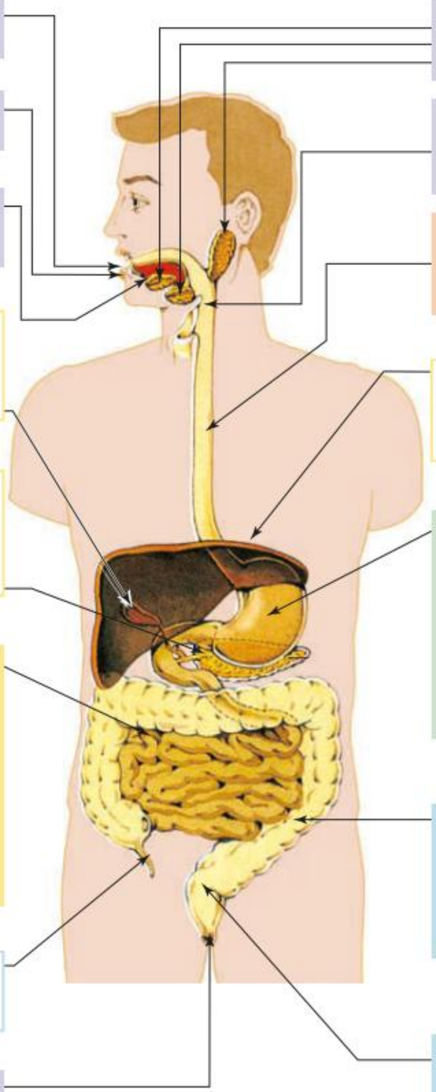
FIGURE 3.25 The digestive system consists of many organs that work together to supply your body with the nutrients it requires.



Oesophagus to stomach

The bolus is then pushed through your **oesophagus** by muscular contractions known as **peristalsis**. From here the bolus is transported to your **stomach,** which secretes acids and enzymes for further digestion and then temporary storage.

oesophagus part of the digestive system composed of a tube connecting the mouth and pharynx with the stomach

peristalsis the process of pushing food along the oesophagus or small intestine by the action of muscles

stomach a large, hollow muscular organ that digests the bolus and secretes acids and enzymes for further digestion and temporary storage

FIGURE 3.26 The stomach is a large, hollow muscular organ.

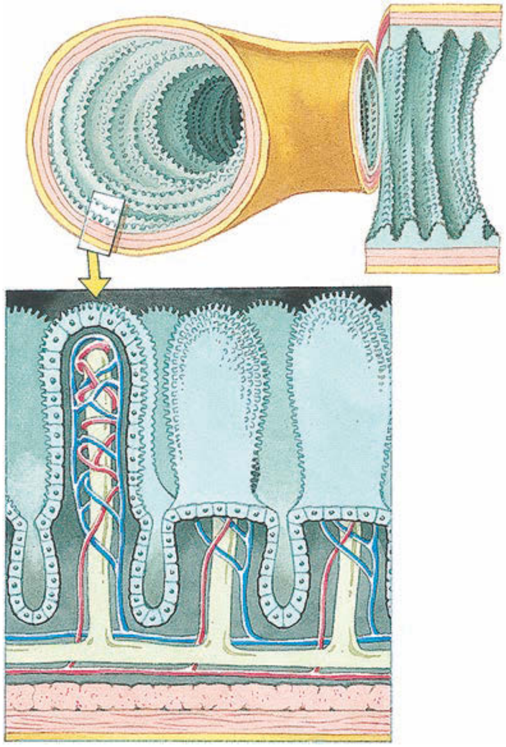
Stomach to small intestine

In your **small intestine**, more enzymes (including amylases, proteases and lipases) turn it into molecules that can be absorbed into your body.

The **absorption** of these nutrient molecules in the small intestines has the following features:

- It occurs through finger-shaped **villi** in the small intestine (figure 3.27). Villi are shaped like fingers to maximise surface area to increase the efficiency of nutrients being absorbed into the surrounding capillaries.
- The absorption of most nutrients into your body occurs in the ileum, the last section of the small intestine.
- Once absorbed into the capillaries (of your circulatory system) these nutrients are transported to cells in the body that need them.
- Undigested material continues on to the large intestine where water and vitamins may be removed.

FIGURE 3.27 The finger-like villi on its walls give it a large surface area that speeds up nutrient absorption.



small intestine the part of the digestive system between the stomach and large intestine, where much of the digestion of food and absorption of nutrients takes place

absorption the taking in of a substance; for example, from the intestine to the surrounding capillaries

villi tiny finger-like projections from the wall of the intestine that maximise the surface area of the structure to increase the efficiency of nutrient absorption. Singular = villus

colon the part of the large intestine where a food mass passes from the small intestine, and where water and other remaining essential nutrients are absorbed into your body

large intestine the penultimate part of the digestive system, where water is absorbed from the waste before it is transported out of the body

rectum the final section of the digestive system, where waste food matter is stored as faeces before being excreted through the anus

anus the final part of the digestive system, through which faeces are passed as waste

Large intestine

All undigested food moves from the small intestine to the **colon** of the **large intestine**. It is here that water and any other required essential nutrients still remaining in the food mass may be absorbed into your body. Vitamin D manufactured by bacteria living within this part of the digestive system is also absorbed. Any undigested food, such as the cellulose cell walls of plants (which we refer to as fibre) also accumulate here and add bulk to the undigested food mass.

The **rectum** is the final part of the large intestine and it is where faeces is stored before being excreted through the **anus** as waste.

Accessory digestive organs

Figure 3.25 shows all organs connected to form the digestive system. Other important organs involved in digestion are:

- **pancreas** — produces enzymes such as **lipases**, **amylases** and **proteases** (which break down lipids, carbohydrates and proteins respectively); these enzymes go into the small intestine to further chemically digest food materials (figures 3.28 and figure 3.30)
- **liver** — is the largest internal organ with many functions; in digestion it produces bile that emulsifies lipids such as fats and oils so they can be broken down by lipases, and it plays a large role in the excretory system (see figure 3.29).
- **gall bladder** — is where bile is stored before it is released into the small intestine.

FIGURE 3.28 The pancreas produces enzymes for digestion, and the gall bladder stores bile that emulsifies lipids.

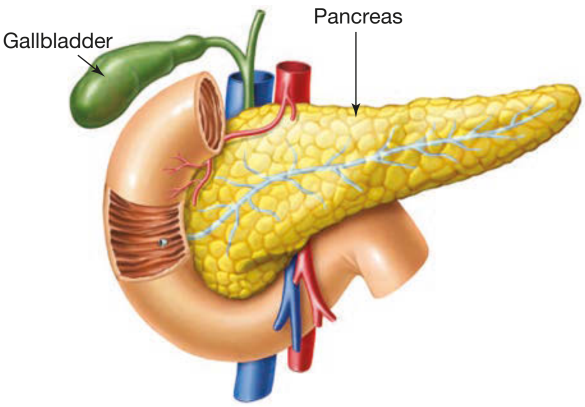


FIGURE 3.29 The liver is a large organ that is like a chemical factory and very important for the body. It is part of both the digestive and excretory system.

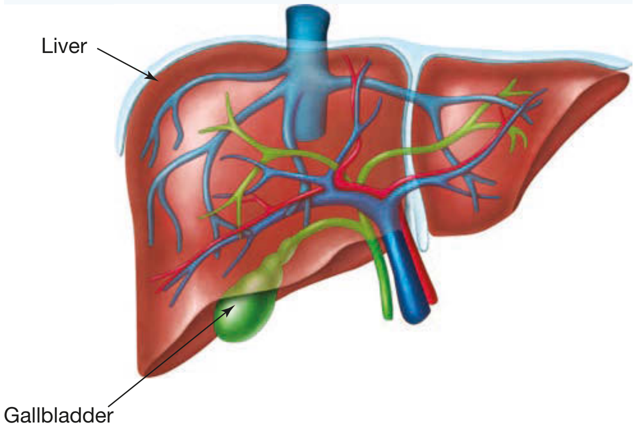
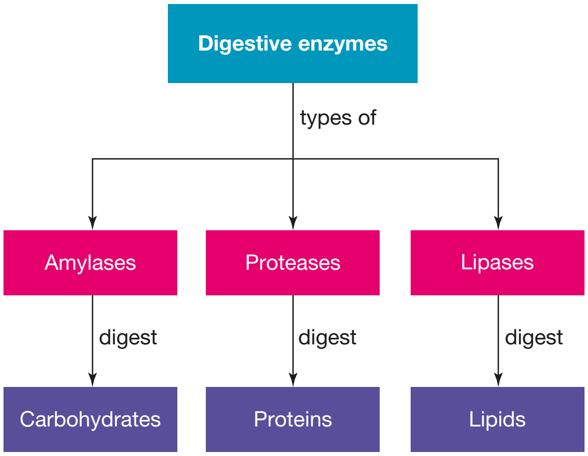


FIGURE 3.30 Different enzymes digest different types of nutrients.



pancreas a large gland in the body that produces and secretes the hormone insulin and an important digestive fluid containing enzymes

lipases enzymes that break fats and oils down into fatty acids and glycerol

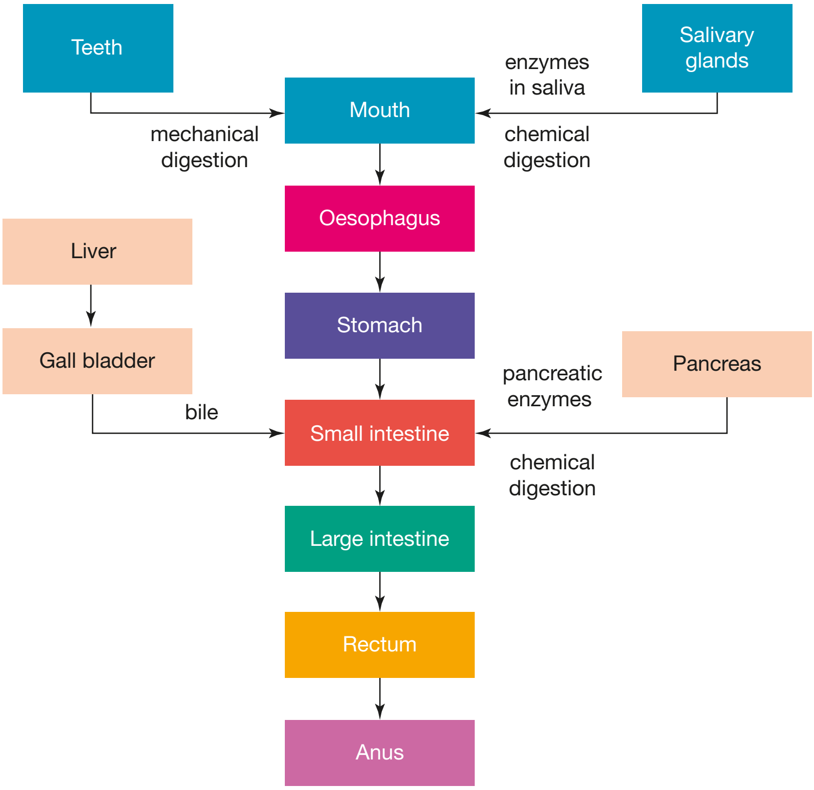
amylases enzymes in saliva that break down starch into sugar

proteases enzymes that break proteins down into amino acids

liver largest gland in the body. The liver secretes bile for digestion of fats, builds proteins from amino acids, breaks down many substances harmful to the body and has many other essential functions.

gall bladder a small organ that stores and concentrates bile within the body

FIGURE 3.31 Digestion occurs within your digestive system in a systematic and organised manner.



3.4.3 The excretory system — Out we go!

Your **excretory system** removes the waste products from a variety of necessary chemical reactions. It helps maintain the proper amount of water, nutrients and salts needed by the body. The main organs involved in human excretion are:

- **skin** — excretes salts and water as sweat
- **kidneys** — involved in excreting the unused waste products of chemical reactions (for example, urea) and any other chemicals that may be in excess (including water) so that a balance within our blood is maintained
- liver — is involved in breaking down toxins for excretion
- lungs — excrete carbon dioxide (produced by cellular respiration) when you breathe out.

excretory system the body system that removes waste substances from the body

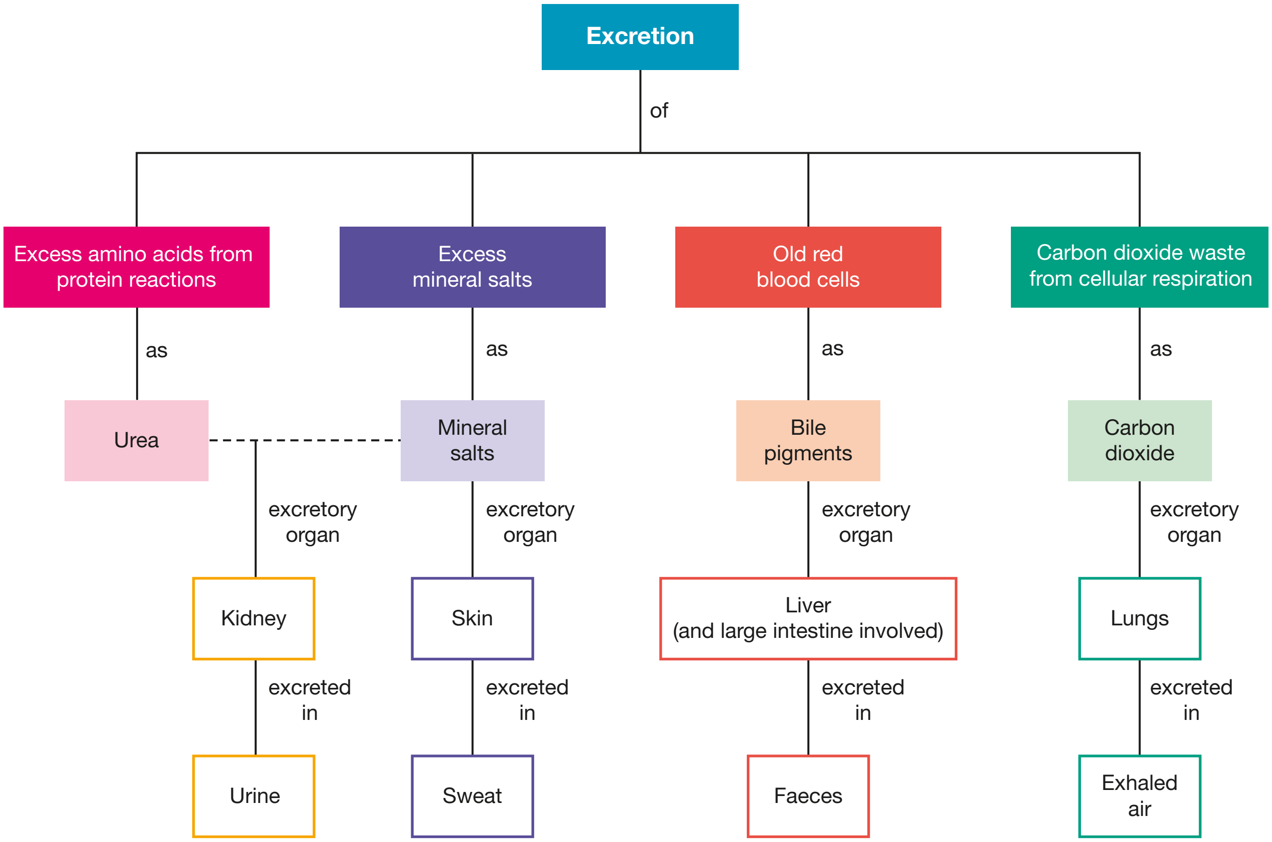
skin external covering of an animal body

kidneys body organs that filter the blood, removing urea and other wastes

Liver

Over a litre of blood passes through your liver each minute. Your liver is like a chemical factory, with more than 500 different functions. We have seen that it removes fats and oils from the blood and modifies them before they are sent to the body's fat deposits for storage. It also helps get rid of excess protein, which can form toxic compounds dangerous to the body. The liver converts these waste products of protein reactions into urea, which travels in the blood to the kidneys for excretion. It also changes other dangerous or poisonous substances so that they are no longer harmful to the body. Your liver is an organ that you cannot live without.

FIGURE 3.32 Flow chart showing your excretory organs and the wastes they excrete.



Kidneys

Your kidneys play an important role in filtering your blood and keeping the concentration of various chemicals and water within appropriate levels.

- Each of your kidneys is made up of about one million **nephrons**.
- Nephrons are tiny structures that filter your blood, removing waste products and chemicals that may be in excess.
- Chemicals that are needed by your body are reabsorbed into capillaries surrounding them.
- The fluid remaining in your nephrons at the end of its journey then travels through to your **bladder** via your **ureters** for temporary storage until it is released as **urine**.

nephrons the filtration and excretory units of the kidney

bladder sac that stores urine

ureters tubes from each kidney that carry urine to the bladder

urine yellowish liquid, produced in the kidneys. It is mostly water and contains waste products from the blood such as urea, ammonia and uric acid.

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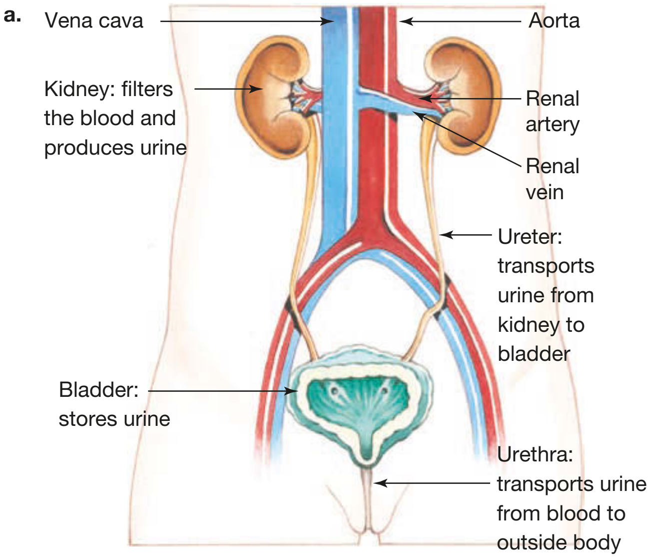
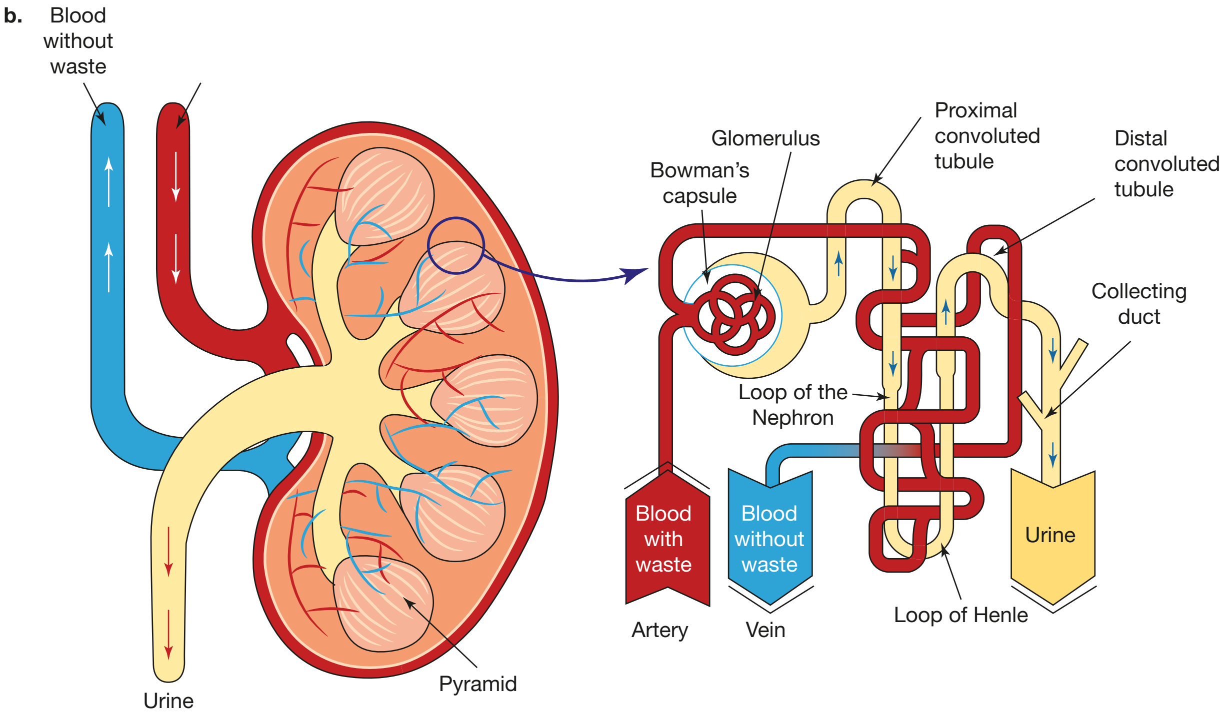
FIGURE 3.33 a. Your kidneys have an important role in the excretion of wastes from your body. **b.** Diagram of a nephron — each of your kidneys is made up of about a million nephrons.





3.4.4 Blood and urine

Both blood and urine are mostly made up of water. Water is very important because it assists in the transport of nutrients within and between the cells of the body. It also helps the kidneys do their job because it dilutes toxic substances and absorbs waste products so they may be transported out of the body.

The concentration of substances in the blood is influenced by the amount of water in it. If you drink a lot of water, more will be absorbed from your large intestine, and the kidneys will produce a greater volume of dilute urine. If you do not consume enough liquid, you will urinate less and produce more concentrated urine.

3.4.5 Blood and carbon dioxide

Lungs

As described in section 3.2.3, your lungs remove carbon dioxide from your body through your respiratory system. Did you know that your body is more sensitive to changes in levels of carbon dioxide than oxygen? If there is too much carbon dioxide in your body, it dissolves in the liquid part of blood and forms an acid. The resulting acidic blood can affect the functioning of your body.

The amount of carbon dioxide in your blood influences your breathing rate. The level of carbon dioxide in the blood is detected by **receptors** in the walls of some arteries and in the brain. If the levels of carbon dioxide in your blood increase, your breathing rate will be increased so that carbon dioxide can be exhaled from your lungs and passed out of your body.

receptors special cells that detect energy and convert it to electrical energy that is sent to the brain.

If you were to climb up high on a mountain, you would need time for your body to adjust. Initially you would feel tired and out of breath because you would be restricted by the limited amount of oxygen available to your cells. Your breathing and heart rate would increase in an effort to get more oxygen around your body. In time, your body would begin to produce more red blood cells and hence more haemoglobin. After this, your breathing and heart rate would return to normal.

DISCUSSION

The amount of oxygen carried by haemoglobin varies with altitude. At sea level, about 100 per cent of haemoglobin combines with oxygen. However at an altitude of about 13 000 metres above sea level, only about 50–60 per cent of the haemoglobin combines with oxygen. This is why mountain climbers sometimes find it difficult to breathe during a climb. What would you suggest they could do to prepare themselves before they begin their climb?

FIGURE 3.34 Climbers on very high mountains, such as Mount Everest, may need to use oxygen stored in tanks.

3.4.6 Systems working together to provide your cells with energy

We know that cells need energy. Glucose is an example of a nutrient that may be released from digested food. It is absorbed in your small intestine and then taken by the capillaries to cells for use in **cellular respiration**. As we saw in the respiratory system (section 3.2.2), glucose is combined with oxygen, and is then broken down into carbon dioxide (a waste product that needs to be removed from the cell) and water. During this reaction, energy in the form of ATP (adenosine triphosphate) is also released. ATP provides the cells with the energy needed to perform many of its activities and is essential to life.

cellular respiration a series of chemical reactions in which the chemical energy in molecules such as glucose is transferred into ATP molecules, which is a form of energy that the cells can use

Cellular respiration:

Glucose + oxygen → carbon dioxide + water + energy (ATP)

This is an example of systems working together. Glucose is supplied via the digestive system and oxygen is supplied via the respiratory system. The circulatory system transports nutrients (such as glucose) and oxygen to your cells and removes wastes (such as carbon dioxide) from your cells. These wastes are then removed from your body by your excretory systems. Without a supply of glucose and oxygen, cellular respiration could not occur. Without removal of wastes, your cells may die. If your systems did not work together like they do, you would not be able to stay alive.

on Resources

eWorkbooks The digestive system (ewbk-4769)
Removing waste from the blood (ewbk-4773)

assesson Additional automatically marked question sets

3.4 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 4, 11, 14, 17, 20	Questions 5, 6, 7, 12, 15, 18, 21	Questions 8, 9, 10, 13, 16, 19, 22

Remember and understand

1. Fill in the blanks to complete the sentence. Digestion involves the breaking down of food so that the__________ it contains can be absorbed into your___________and carried to ____________ in your _____________.
2. Place the following organs in the correct order.
   A. Anus
   B. Large intestine
   C. Mouth
   D. Oesophagus
   E. Small Intestine
   F. Stomach
3. **MC** Identify the name given to the slimy, slippery ball-shape your tongue rolls food into.
   A. Bile
   B. Bolus
   C. Peristalsis
   D. Villi
4. **MC** Identify the name given to the muscular contractions that push food through the oesophagus to the stomach.
   A. Bile
   B. Bolus
   C. Peristalsis
   D. Villi

5. MC In which part of the digestive system does most of the absorption of nutrients occur?
   A. Large intestine
   B. Mouth
   C. Small intestine
   D. Stomach
6. Match the organs of the digestive system with their function.

Organ	Function
a. Gall bladder	A. Stores faeces
b. Large intestine	B. Makes enzymes used in the small intestine
c. Liver	C. Temporary storage of food and where protein digestion begins
d. Oesophagus	D. Where the breakdown of starch and protein is finished and fat breakdown occurs
e. Pancreas	E. Tube that takes food to the stomach
f. Rectum	F. Stores undigested food and waste while bacteria make some vitamins
g. Small intestine	G. Stores bile until needed by the small intestine
h. Stomach	H. Makes bile, stores glycogen and breaks down toxins

7. Match the organs of the excretory system with their function

Organ	Function
a. Bladder	A. Watery fluid produced by kidneys thatb contains unwanted substances
b. Kidney	B. When urine moves from the bladder, through the urethra and out of the body
c. Ureter	C. Transports urine from bladder to outside body
d. Urethra	D. Fitters the blood and produces urine
e. Urination	E. Stores urine
f. Urine	F. Transports urine from kidneys to bladder

8. Identify examples of types of enzymes involved in the digestion of:
   a. carbohydrates
   b. proteins
   c. lipids.
9. Explain why the villi in the small intestine are the shape that they are.
10. Outline a way in which the liver is involved in digestion.
11. Identify the part of the digestive system in which water is absorbed into your body.
12. Is cellulose digested? What happens to it?
13. a. Define the term *excretion*.
    b. List examples of organs that are involved in human excretion.

Apply and analyse

14. Describe what happens when you drink a lot of water.
15. Suggest reasons why you can't live without your liver.
16. Identify the name given to the:
    a. tiny structures that make up the kidney
    b. fluid that travels from your kidneys to your bladder for excretion.
17. Suggest why a supply of water is important to your cells.
18. Construct flow charts to show the route travelled:
    a. by nutrients (for example, glucose) as they are absorbed into your body
    b. by undigested food material travelling from your mouth to your anus.
    c. by water in the renal artery, through the nephron to the urethra.
19. Is your body more sensitive to changes in carbon dioxide or oxygen levels? Explain.

Evaluate and create

20. Use Venn diagrams to compare:
    a. the digestive system and excretory system
    b. the small intestine and large intestine
    c. ingestion and egestion
    d. proteases and lipases
    e. cellulose and glucose
    f. bile and enzymes
    g. ureter and urethra
    h. nephron and villi
    i. the digestive system and respiratory system
    j. the excretory system and circulatory system.
21. SIS Use the table and the other information in this subtopic to answer the following questions.
    a. Draw two bar graphs to show the quantity of water, proteins, glucose, salt and urea in blood and in urine.
    b. Which substance is in the greatest quantity? Suggest a reason for this.
    c. Which substances are found only in blood?
    d. Which substances are found in urine in a greater quantity than in blood? Suggest a reason for this.
    e. When would the amount of these substances in the urine become greater or less than in the blood?

TABLE Substances in blood and urine as a percentage of total

Substance	Quantity (%)	
	In blood	In urine
Water	92	95
Proteins	7	0
Glucose	0.1	0
Chloride (salt)	0.37	0.6
Urea	0.03	2

22. SIS An investigation is being conducted to explore how the function of the circulatory and excretory systems change during exercise.
    a. Write a suitable aim for this investigation.
    b. Identify the hypothesis for this investigation.
    c. Describe one piece of numerical (quantitative) data and one piece of visual (qualitative) data that can be collected.
    d. Explain two factors that may lead to differences in results between different students.
    e. Write a clear methodology for this investigation, with an explanation of how you will collect results
    f. Which other body systems are needed to maintain a healthy body during exercise?

Fully worked solutions and sample responses are available in your digital formats.

3.5 Living warehouses

LEARNING INTENTION

At the end of this subtopic you will be able to describe how the body controls blood glucose levels to provide enough energy for cellular respiration and how this process can breakdown, and how different foods can be used by the body.

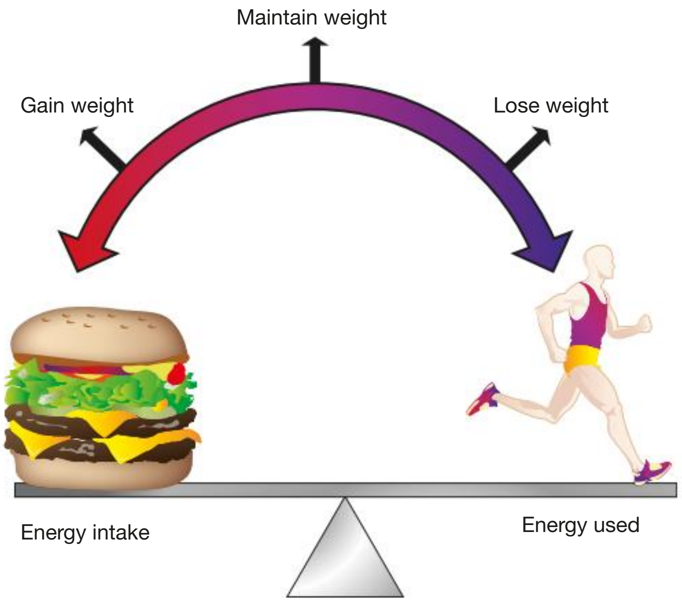
3.5.1 Living warehouses

It can be confusing trying to figure out what a healthy diet is when you are bombarded by so many different fad diets! Many of these diets eliminate whole food groups and may put you at risk of developing a nutritional deficiency. Knowing how your body stores and uses energy — like a living warehouse — may help you to weigh up the risks and benefits of these 'wonder diets'.

To function effectively, your body needs energy. We gain energy from the foods that we eat. The amount of energy stored in this food is measured in kilojoules (kJ) or calories.

The amount of energy that you need depends on how big and active you are, how quickly you are growing and how fast your body uses it.

FIGURE 3.35 To maintain a healthy weight, it is important to balance your energy intake with the energy you use.



3.5.2 Balancing blood glucose

Your cells need glucose to use in the process of cellular respiration to make **ATP** (adenosine triphosphate) molecules. ATP is used by cells in reactions that require energy. This glucose is obtained from the food that you eat. Glucose molecules are transported in blood in your circulatory system to cells throughout your body.

If you have high levels of glucose in your blood:

- Special cells in your pancreas detect this and release **insulin** into your bloodstream.
- Target cells in your muscles and liver receive this chemical message and glucose is taken out of the blood and converted into the storage polysaccharide **glycogen**.

If the levels of blood glucose are too low:

- Another hormone, **glucagon,** is released by the pancreas.
- Glucagon triggers the breaking down of glycogen into the monosaccharide glucose. This is how the glucose levels in the blood can be kept within a narrow range.

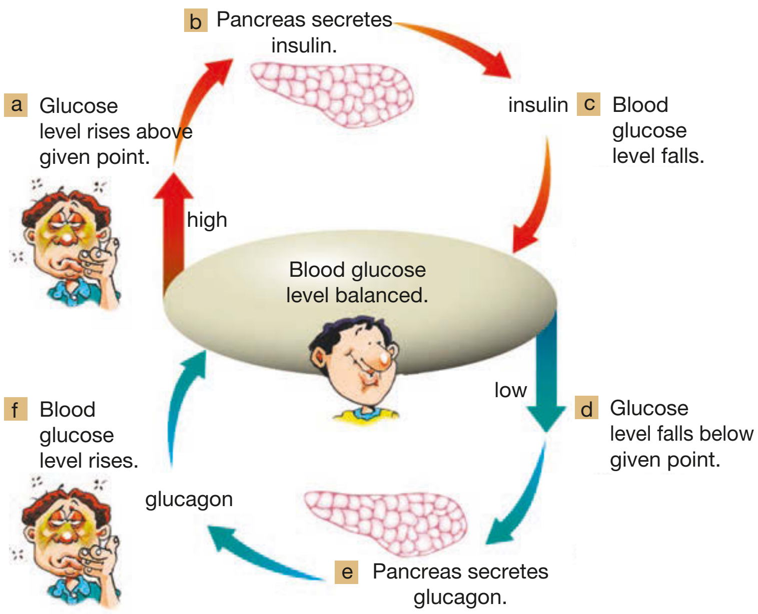
ATP molecule used by cells in chemical reactions that require energy. ATP is a product of cellular respiration.

insulin hormone that removes glucose from the blood and stores it as glycogen in the liver and muscles

glycogen the main storage carbohydrate in animals, converted from glucose by the liver and stored in the liver and muscle tissue

glucagon a hormone, produced by the pancreas, that increases blood glucose levels

FIGURE 3.36 The hormones insulin and glucagon are secreted by the pancreas to control glucose levels in your blood.



CASE STUDY: Diabetes

Diabetes mellitus is an endocrine disorder. Features of diabetes include:

- It is caused by a deficiency of insulin or a loss of response to insulin in target cells (such as those in liver and muscle tissue).
- Deficiency or loss of response to insulin results in high blood glucose levels.
- Glucose levels can become so high that it is excreted by your kidneys and hence found in urine. Glucose in urine is one of the tests that are indicative of diabetes.
- The higher the glucose levels, the more water will be excreted with it. This results in the loss of large volumes of urine, which leads to persistent thirst; this is one of the warning signs for diabetes mellitus.

FIGURE 3.37 People with diabetes may need to inject insulin to control their blood glucose levels.

There are two main types of diabetes.

1. **Type 1 diabetes mellitus** usually starts in childhood and is an autoimmune disorder. In this case, the immune system mounts an attack against cells in the pancreas, destroying their ability to produce insulin. This type of diabetes requires treatment with insulin injections.
2. **Type 2 diabetes mellitus** usually starts later in life and is the most common form. It is characterised by either a deficiency of insulin or target cells that do not respond effectively to insulin. Type 2 diabetes has been linked to hereditary factors and obesity. It is usually controlled through exercise and diet.

diabetes mellitus a medical condition in which the liver cannot effectively convert glucose to glycogen

Type 1 diabetes mellitus a disease in which the pancreas stops producing insulin, so the body's cells cannot turn glucose into energy

Type 2 diabetes mellitus the most common form of diabetes, where the pancreas makes some insulin but does not produce enough

3.5.3 GI: High or low?

You may have noticed that some foods are labelled as 'low GI' or 'high GI'. This refers to the **glycaemic index** of the food.

glycaemic index (GI) a measure of how quickly a particular food raises the level of blood sugar over a two-hour period

The glycaemic index of food is a measure of the time it takes for your blood sugar level to rise after you have eaten it. Foods with a high glycaemic index can cause a sharp rise in blood sugar.

Foods that are considered to be low GI are digested more slowly than those that are high GI. This means that blood glucose levels will rise more slowly and over a longer period of time, which means you will feel fuller for longer. High GI foods provide a short burst of glucose and you may start to feel hungry as your blood glucose levels drop.

Foods with a high GI

Foods with a high glycaemic index:

- contain starch and sugar, which are porous and have a high surface-to-volume ratio
- can be digested easily by the enzyme amylase and can cause a sharp rise in blood sugar
- includes foods such as white bread, rice and mashed potatoes. These foods are very good if you have been active and need to replenish energy stores quickly.

Foods with a low GI

Foods with a low glycaemic index:

- are rich in fibre and so are digested more slowly
- are foods that have a more compact physical form makings it harder for the enzyme amylase to reach its substrate
- includes foods such as wholemeal bread and thick pasta like spaghetti and nuts. These foods cause only a moderate change in your blood sugar level, so can help provide you with lasting energy throughout your day.

Table 3.1 indicates the glycaemic index of a range of foods, and the graph at figure 3.39 shows the energy spike and drop that occurs after eating high GI foods and the more moderate, longer lasting rise in blood sugar level after eating low GI foods.

FIGURE 3.38 Foods with a lower GI release energy more slowly and help you to feel full for longer.

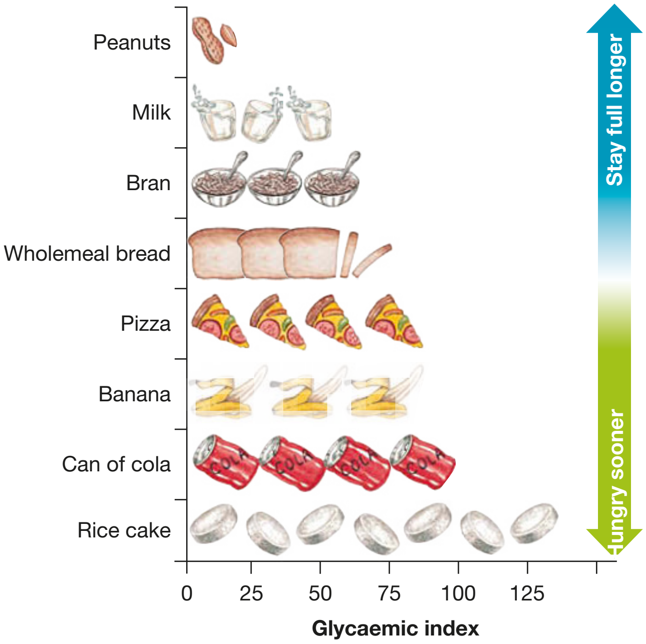


FIGURE 3.39 Foods with a high GI, such as chocolate, cause a sharp rise in blood sugar. Foods with a low GI, such as nuts, result in a more moderate but longer lasting rise in blood sugar.

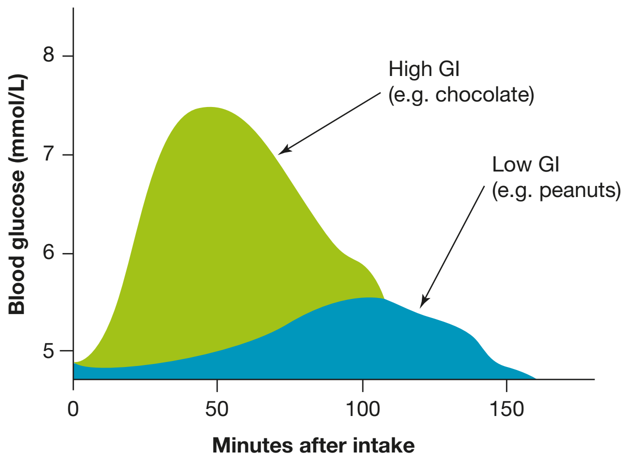


TABLE 3.1 Glycaemic index across a range of foods

Category	Extremely high	High	Moderately high	Moderately low	Low
Grains	Puffed rice Cornflakes White bread	Wholemeal bread Muesli Brown rice Porridge oats	Bran Rye bread White pasta Brown pasta	Tomato soup Lima beans	Barley
Fruits and vegetables	Parsnip Baked potato Carrot	Sweetcorn Mashed potato Boiled potato Apricots Bananas	Sweet potato Peas Baked beans Grapes Orange juice	Pears Apples Orange Apple juice	Red lentils Soybeans Peaches Plums
Sugar	Glucose Honey	Sucrose			
Snacks		Corn chips Chocolate Crackers Biscuits Low-fat ice-cream	Potato chips Sponge cake	Yoghurt High-fat ice-cream	Peanuts

CASE STUDY: How penguins survive the winter

When food supplies are scarce, or during hibernation, an animal's ability to store energy reserves greatly assists its chances of survival. Penguins, for example, use their fat reserves to provide them with energy when required. Male emperor penguins are able to keep eggs warm for nine weeks at a time without any food. Animals that live in cold regions also use their fat storage ability to insulate themselves against the very cold weather conditions. Whales and seals have a thick layer of fat cells called blubber, which serves as an insulation layer in their cold, watery habitats.

3.5.4 Fats, feasts and famines

Fats are particularly high in energy, providing about twice as much energy as the equivalent amount of carbohydrate or protein.

When more kilojoules of energy are consumed than required, the body tends to store the excess energy in the liver and muscle cells as glycogen. If glycogen stores are full and the energy intake still exceeds that required, the excess may be stored as fat in the form of fat cells just beneath the skin.

When extra energy is required, the liver glycogen is used first, then the muscle glycogen and finally the fat. Most people have enough fat cells stored to provide energy for 3–7 weeks. The human body tends to hoard fat, immediately storing fat molecules obtained from food.

Most people should consume about 30–40 g of fat a day.

The amount of fat in your diet can have a more direct effect on weight gain than carbohydrates. Although fat hoarding can have a negative effect on our health today, it may have increased the chances of survival of your hunting and gathering ancestors. Recent discoveries suggest that the regulation of fat storage may be controlled by a hormone called leptin and several genes inherited from your parents.

fats organic substances that are solid at room temperature and are made up of carbon, hydrogen and oxygen atoms

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INVESTIGATION 3.2

Measuring the energy in food

Aim

To compare the amounts of energy stored in a range of foods

Materials

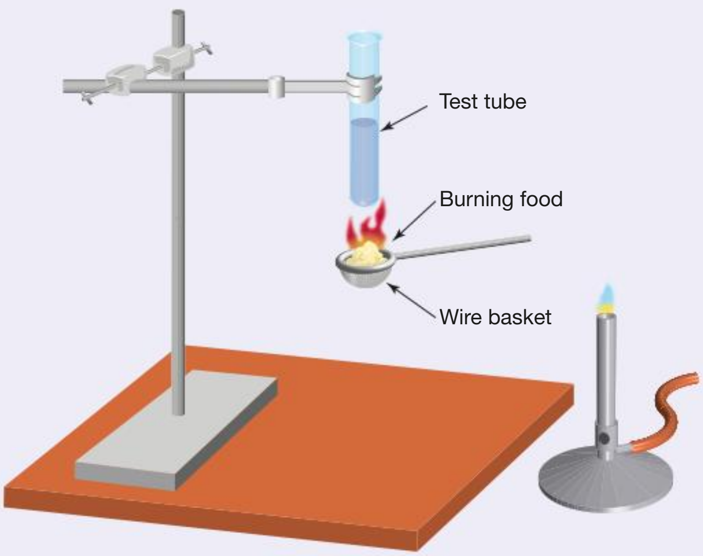
- small metal basket (used to fry food)
- samples of small biscuits, potato chips, uncooked pasta, crouton or small piece of toast
- safety glasses
- thermometer
- retort stand, bosshead and clamp
- large test tube
- Bunsen burner
- measuring cylinder
- water
- electronic balance

CAUTION

Before starting this experiment, read all the steps below and make a list of the risks associated with this activity and how you plan to minimise these risks.

Method

1. Use the clamp to attach the test tube to the retort stand.
2. Measure 30 mL of water and pour it into the test tube.
3. Measure the temperature of the water.
4. Weigh the biscuit.
5. Place the small biscuit in the wire basket and set fire to it using the Bunsen burner. When the biscuit is alight, put the basket containing the biscuit underneath the test tube. The heat released from the burning biscuit will heat the water. Hold the basket under the test tube until the biscuit is completely burned. You can tell that the biscuit is completely burned if it is all black and will not re-ignite in the Bunsen burner flame.
6. Measure the temperature of the water again.
7. Repeat the steps above using the other food samples.



Results

1. Use the table to record your results

TABLE Results of investigation 3.2

Measurement	Biscuit	Chip	Pasta	Crouton/toast
a. Mass of food (g)				
b. Volume of water (mL)				
c. Initial temperature of water (°C)				
d. Final temperature of water (°C)				
e. Increase in temperature (= $d - c$)				
f. Energy in food (J) (= $4.2 \times 30 \times e$)				
g. Energy in food (kJ) (= $f \div 1000$)				
h. Energy per gram of food (kJ/g) (= $g \div a$)				

2. Calculate the amount of energy that was stored in the biscuit, using the following equation.

$$\text{Energy (in joules)} = 4.2 \times \text{volume of water (in mL)} \times \text{increase in temperature (in °C)}$$

3. Calculate the amount of energy per gram of food by dividing the amount of energy by the mass of the food in grams.

Discussion

1. Why was it necessary to calculate the amount of energy per gram of food?
2. Did all the heat from the burning food go into heating the water? Explain how this might have affected the validity of this experiment.

Conclusion

Write a conclusion to your experiment, referring back to your aim.

3.5.5 How much sugar?

To calculate how much sugar is in a can or bottle of drink you must first find the nutrition information section on the label. A typical non-diet soft drink might contain 11.04 grams in 100 mL.

To calculate the mass of sugar in one 375 mL can of drink, use the formula below:

$$\text{Mass of sugar} = \frac{11.04 \times \text{volume}}{100}$$

$$\text{So, mass of sugar} = \frac{11.04 \times 375}{100} = 41.40 \text{ g}$$

Since one teaspoon of sugar has a mass of approximately 4 grams, divide the mass of sugar in one can of drink by 4.

Therefore, one can of soft drink might contain over 10 teaspoons of sugar.

$$\frac{41.40}{4} = 10.35 \text{ teaspoons}$$

FIGURE 3.40 Sugar content of some common drinks

DISCUSSION

Imagine being told 'No treats for you! You will have spinach, capsicum and tomato on wholegrain bread and no butter!' Who tells you what to eat? Should you listen? Do others really care what you put into your mouth?

In 2006, the Victorian government decided to address the types of food that are available to school students. One of the reasons for this was the growing concern about the number of obese children in the state. Soft drinks containing sugar were the first to be on their no-go list. Do you think the government has the right to make such a decision? What is your opinion on this issue?

What other lifestyle habits should the government be involved in? How should they approach this? Provide reasons why you think they should be involved.

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INVESTIGATION 3.3

Energy for living

Aim

To increase awareness of energy intake from food and energy output during different types of activities

Method

TABLE Energy used for a variety of activities

Activity	Approximate energy use (kJ) per hour
Sleeping	250
Very light: sitting, reading, watching television, driving	450
Light: leisurely walking, washing, shopping, light sport such as golf	950
Moderate: fast walking, heavy gardening, moderate sports such as cycling, tennis, dancing	1800
Heavy: vigorous work, sports such as swimming, running, basketball and football	3500

TABLE Energy and fat levels in a range of foods

Food	Energy (kJ)	Fat (g)
Pizza (two slices)	2060	20
Hamburger	1900	20
Salad sandwich	940	9
Chocolate eclair	1320	15
Fresh fruit salad	290	0.3
Apple pie with ice-cream	2310	26
Medium cola	384	0
Strawberry thick shake	1230	15
Medium orange juice	530	0

1. In this investigation you will record all the activities that you have been involved in over a 24-hour time period. Complete the table in the Results section by calculating the energy used for each activity.
2. Select a two-course lunch and a drink from the previous table, or choose your own lunch and research the energy content.

Results

1. Construct a table with the headings as shown below.

TABLE Duration of activities and energy used

Activity	Time spent on activity in hours or part of an hour	Energy use (kJ) per hour (from the provided table)	Total energy used (in kJ)

2. Calculate your total energy (kJ) used during the 24-hour period.
3. Record what you ate for lunch and calculate the energy content.

Discussion

1. Which activity used the most energy?
2. Subtract the energy value of your lunch from the total energy used in 24 hours.
3. Based on the value calculated in question 2, how many kilojoules could you eat for breakfast and dinner to balance the rest of the energy used that was calculated in your Results? Comment on this amount.
4. Comment on the amount of fat (g) calculated in your selected meal.
5. Suggest why the values of energy used in daily activities are only approximate.
6. Identify the strengths and limitations of this investigation and suggest how it could be improved.

7. Propose a related research question that could be explored.
8. Suggest a hypothesis relevant to your research question.
9. Design an investigation that could test your hypothesis.

Conclusion

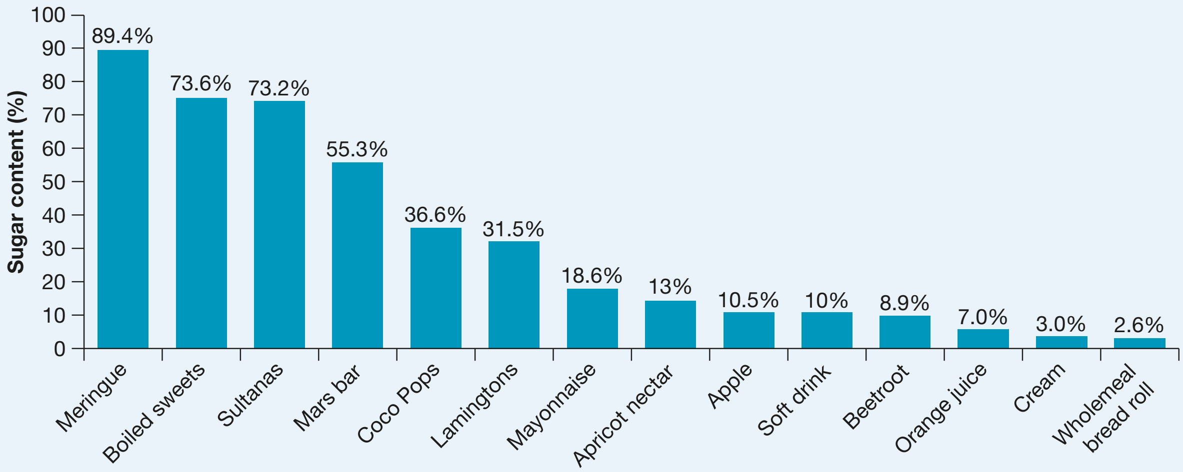
Write a conclusion to your investigation, referring back to your aim.

ACTIVITY: Fizz and tell

The aim of this activity is to increase awareness of the amount of sugar in soft drinks and other common foods. In this activity you will calculate the amount of sugar consumed in a week in your class, and you will analyse data.

1. Survey the class to find out:
   a. how much soft drink (or other sugary food) they consume in a week (in millilitres)
   b. which types of soft drinks are consumed.
2. Present your results in a format that can be shared with others.
3. Comment on your results. Were they what you expected or were you surprised? Were there patterns? What other sorts of information would you like to know to further analyse the data?
4. Comment on whether your data support the following statement: 'Almost 80 per cent of teenagers consume soft drinks weekly, with 10 per cent drinking more than one litre per day.'

FIGURE 3.41 Sugar content of some common foods



EXTENSION: More fizz and tell

This activity aims to extend your analysis of the amount of sugar consumed in a week. Here you will critically evaluate the relationship, if any, between soft drink consumption and teenage obesity.

Consider the following statement:

'Sugar-loaded soft drinks should be banned from all Australian schools to reduce teenage obesity.'

1. Construct a PMI chart on the statement.
2. Do you agree with this statement?
3. In the classroom, construct a human graph to show people's opinions on the statement. Stand in positions to indicate your feelings about the statement. For example:
   - Strongly disagree (0) — stand next to the left-hand wall
   - Agree (2) — stand in the centre of the room
   - Strongly agree (4) — stand next to the right-hand wall.

4. Have a discussion with students standing near you to find out the reasons for their opinion.
5. Listen to the discussions of students in other positions.
6. Construct a SWOT diagram to summarise what you have found out.
7. Record the results of the human graph.
8. a. What was the most popular attitude? Suggest a reason for this.
   b. What was the least popular attitude? Suggest a reason for this.
   c. Do you think this attitude pattern is representative of other Australians your age? Explain.
9. On the basis of your discussions, have you changed your attitude since the start of this activity? If so, how is it different and why?

on Resources

assesson Additional automatically marked question sets

3.5 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

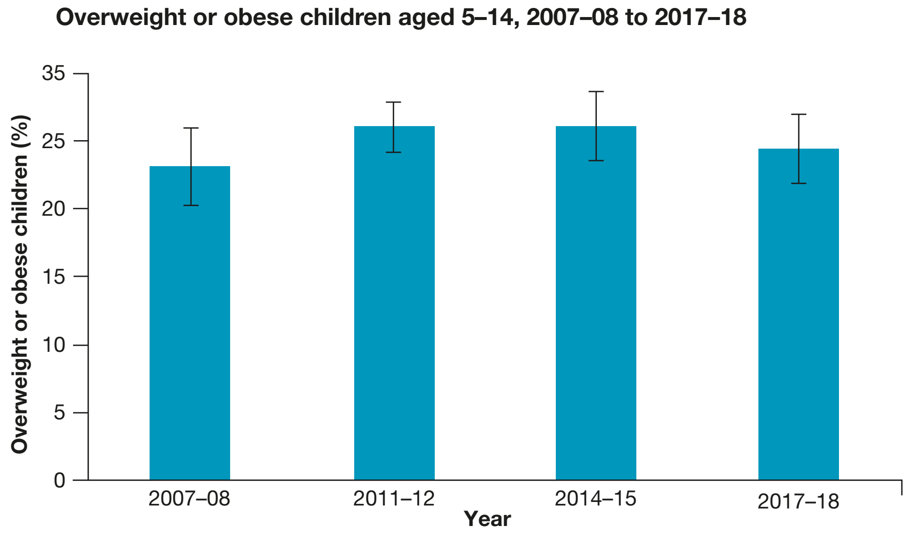
1. Name the unit in which energy is often measured.
2. Explain why your cells need glucose.
3. Describe how your:
   a. cells obtain glucose
   b. blood glucose levels are kept within a narrow range.
4. Explain what happens when we eat more kilojoules than we use.
5. Outline two ways in which fat storage assists the survival of animals.

Apply and analyse

6. Compare and contrast:
   a. high GI foods and low GI foods
   b. Type 1 diabetes and Type 2 diabetes
   c. carbohydrate storage and fat storage.
7. Describe the relationship between:
   a. insulin and glucagon
   b. glycaemic index of foods and sugar levels
   c. a diet high in kilojoules and no weight gain.

Evaluate and create

8. SIS



a. In 2017–2018 what percentage of children in Australia were overweight or obese?
b. Describe the trends in the incidence of childhood obesity in Australia from 2007–2008 to 2017–2018. Were any of the changes statistically significant? (*Hint*: Look at the error bars on the graph provided).
c. Based on the information given and your own knowledge, what are the advantages of maintaining a healthy weight?

Evaluate and create

9. SIS Use the data in the table, which shows recommended energy intakes, to answer the following questions.
a. Plot a graph to show how energy needs change with age. You will need to plot two lines: one for males and one for females. The age should be on the horizontal axis. (If a computer is available, you could use a spreadsheet.)
b. Suggest why females seem to need less energy.
c. Suggest why you need more energy as you approach your late teens.

TABLE Recommended energy intake per age group

	Recommended daily energy intake (kJ)		
Group	**Age**	**Male**	**Female**
Children	1	5000	4800
	5	7600	6800
	9	9000	7900
Adolescents	12	9800	8600
	13	10 400	9000
	14	11 200	9200
	15	11 800	9300
Adults (height 190 cm)	18–30	12 000	10 600
	30–60	11 400	9500
	over 60	9700	8800

Fully worked solutions and sample responses are available in your digital formats.

3.6 Myths, moods and foods

LEARNING INTENTION

At the end of this subtopic you will be able to evaluate the validity and reliability of claims common in folk legends and in the media, and be able to recognise the importance of evidence-based arguments.

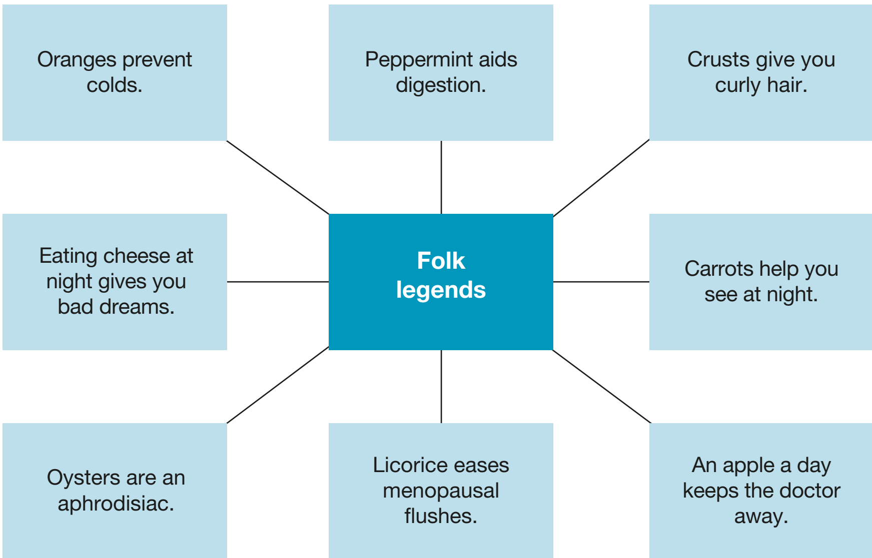
3.6.1 Folk legends

Knowledge often passes from one generation to the next through stories and tales. Some old-fashioned remedies have been passed on in this way. The truth of some of these folk legends may have altered or disappeared along the way, while others may have a sound basis.

For instance, is chicken soup good for fevers? Yes; but this is also true for many other protein-rich foods. Although your body produces about 2000 immune cells per second, many of these can be lost when you are feverish. The amino acids in proteins help you to reinforce and rebuild new immune cells and molecules.

There are many folk legends related to food, and some of these are shown in the bubble map in figure 3.42.

FIGURE 3.42 Bubble map of folk legends related to food



3.6.2 Mood food

Ever heard of 'mood food' or 'comfort food'? Do you crave particular foods when you are in a particular mood? Some foods don't just make you feel happy, but actually affect your brain. The article *Diet to lift spirits* discusses some recent research on the antidepressant properties of two key nutrients.

Foods that may affect your mood

- **Dark chocolate** (at least 70 per cent cocoa solids) contains catechins, which are strong antioxidants that enhance endorphins, the brain's natural feel-good chemicals, and increase libido.
- **Seafood** and oily fish contain high levels of omega-3 essential fatty acids, which are the nerve and brain cells' building blocks that will ultimately improve mood more than any other food.
- **Nuts, seeds** and legumes such as beans and lentils contain tryptophan, a protein converted into the brain chemical serotonin, which is usually low in people with depression.

- **Chicken, turkey emu meat** and other **wild game** also contain high levels of EFAs.
- **Caffeine** boosts mental alertness and concentration. But many regular tea and coffee drinkers then feel the unpleasant symptoms of caffeine withdrawal when they don't get their daily cuppa.
- **Carbohydrate** cravings may be a subconscious attempt to raise levels of serotonin, as tryptophan is absorbed more quickly into the brain after eating carbohydrate 'comfort food' such as potatoes.
- **Junk food** has high levels of sugar and animal fats, which send blood sugar and endorphin levels soaring, giving you an instant hit. But the effect is short-lived, and is followed by quickly plunging blood sugar and energy levels downward, sending you into depression, so the overall effect is bad.

CASE STUDY: *Diet to lift spirits*

By Fay Burstin

We know them as comfort foods — those warm hearty meals or rich treats — because the mere act of eating them makes us happy.

But research suggests that consuming the right foods could make us feel so good they could even relieve depression.

Two key nutrients in fish, nuts and beets have been found to work just as well as prescription antidepressants in preventing depression in laboratory rats.

Harvard University researchers in the US found omega-3 fatty acids and uridine, both linked to improved brain function, affected the rats' behaviour during a standard depression test.

Rats forced to swim in chilled water with no way to escape will normally become hopeless and float motionlessly. But when treated with antidepressants, they remain active for longer, searching for an escape.

A team led by neurobiologist William Carlezon at Harvard-affiliated McLean Hospital found rats whose diets were supplemented with high levels of omega-3 fatty acids for at least 30 days stayed active and focused on escape.

Similarly, the study published in Biological Psychiatry found rats injected with high levels of uridine were equally tenacious.

And combined doses of omega-3 oil and uridine were just as effective as three different antidepressants in prompting the rats to start swimming again, Dr Carlezon said. But they didn't see the same results in untreated rats.

Dr Carlezon speculated that the drugs and dietary supplements acted on brain cells' mitochondria, the power source that produces energy for cells.

'Imagine what happens if your brain does not have enough energy,' he said.

'Basically, we were giving the brain more fuel on which to run.'

Associate Professor Luis Vitetta, from Swinburne University's Graduate School of Integrative Medicine, said major medical advances had been made in recent years linking illnesses such as cancer and cardiovascular disease to diet.

Now, similar links were being drawn between nutrition and brain function disorders such as dementia, ADHD, depression and bipolar disorder, he said.

'We're starting to put the pieces of the puzzle together, based largely on why some cultures with certain diets suffer less from these disorders than others,' he said.

'Japan had one of the world's lowest rates of depression and we're beginning to think it's because they eat oily fish like salmon every day that's rich in omega-3 essential fatty acids.'

Dr Vitetta said at least 50 per cent of our brain was made up of essential fatty acids (EFAs).

But our brain can't manufacture EFAs itself so we need to get them from our diet.

Dr Vitetta said research showed anyone (or anything, including lab rats) fed omega-3 fatty acids performed better on brain function tests.

Studies show dyslexic children given an omega-3 dietary supplement can make two years' reading progress in six months and 70 per cent of kids diagnosed with ADHD no longer met the clinical criteria after four months of taking an EFA supplement.

But it's not just EFAs we need to lift our mood and brain power.

Dr Vitetta said good nutrition, including at least five or six portions of fresh fruit and vegetables a day, could ultimately have the same effect on the brain as antidepressant drugs.

'The vitamins and minerals in fresh fruit and vegetables are crucial for every bodily function, including the heart, the liver and the gastrointestinal system,' he said.

'When your body is working well, your weight is healthy and your skin looks good, all of which have a positive effect on your self-image'.

'And if you feel good about yourself, you're less likely to feel anxious and depressed, which is reflected in good mental health.'
***Source*:** *Herald Sun*

DISCUSSION

Consider the experiments performed on rats at Harvard University described in the article *Diet to lift your spirits* above. How do you feel about this treatment of the rats? How do you think others may view these experiments and their outcomes?

3.6.3 Omega-3 oil

When your great-grandparents were children, many were given a daily dose of cod-liver oil to maintain good health. It turns out that your great-grandparents may have been right about the benefits of fish oil. Fish oil is rich in omega-3 fatty acids. DHA (docosahexaenoic acid) is an omega-3 oil important for brain, nerve and eye tissue development. The highest concentration of omega-3 DHA in the human body is in the retina of the eye. These fatty acids are being investigated as a possible treatment for conditions including rheumatoid arthritis, depression, attention deficit disorder and heart disease.

FIGURE 3.43 Omega-3 fatty acids are found in oily fish (for example, tuna), some seeds and vegetable oils, and supplements.

A number of scientific studies have shown that omega-3 fatty acids affect behaviour and mood. For example, Bernard Gesch carried out an experiment involving British prison inmates. He gave half the people who had volunteered for his study a daily supplement that contained omega-3 fatty acids and other vitamins and minerals. The other prisoners were given a placebo (a tablet that looked just like the supplement but did not contain fatty acids, vitamins or minerals). Over time, he found that the prisoners taking the supplement were involved in a lot fewer violent incidents. The prisoners taking the placebo showed no significant change in their behaviour.

SCIENCE AS A HUMAN ENDEAVOUR: Research into omega-3 oil

Dr Lisa Smithers won the 2008 South Australian Young Investigators Award for her research on omega-3 oils, tuna oil and premature babies.

Premature babies may have low levels of DHA and rely on milk to supply it to them after their birth.

Dr Smithers's PhD research at the University of Adelaide involved a clinical trial. One group of breastfeeding mothers ingested tuna oil capsules with DHA. This raised the levels of DHA in the milk to four times higher than would normally be present. The DHA-enriched milk was provided until the premature babies reached their full-term date. The other group of mothers received placebo capsules that did not contain DHA.

FIGURE 3.44 Although they may look like jelly beans, these are omega-3-oil supplements.

Testing the babies at four months of age showed that those who were fed higher levels of DHA were able to visually detect a finer pattern than those who had not. This suggests that the addition of DHA to the milk assisted in their visual development.

on Resources

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3.6 Exercise

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To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Suggest why you might get cravings for carbohydrates.
2. What are the benefits of ingesting caffeine?
3. Describe the effect of junk food on your endorphin and sugar levels.

Apply and analyse

4. Suggest why chicken and lentils might be good to eat when you are depressed.
5. Read through the text entitled 'CASE STUDY: *Diet to lift spirits*' and respond to the following questions.
   a. Identify in which foods you would find the two key nutrients that act as antidepressants in depressed laboratory rats.
   b. State the names of these antidepressant-type nutrients.
   c. Identify which part of the brain cells Dr Carlezon suggested the drugs acted on.
   d. List some links that were drawn between nutrition and brain function disorders.
   e. Suggest why it is thought that Japan may have one of the world's lowest rates of depression.
   f. What does EFA stand for?
   g. State the percentage of our brain that is made up of essential fatty acids.
   h. Describe the results of studies on dyslexic children given an omega-3 dietary supplement.

Evaluate and communicate

6. **SIS** Read through the text entitled 'SCIENCE AS A HUMAN ENDEAVOUR: Research into omega-3 oil' and respond to the following questions.
   a. Which of the two groups in her clinical trial were the control group? Why?
   b. State the independent and dependent variables in her clinical trial.
   c. Suggest which variables she would have needed to control.
   d. In the clinical trial, some of the mothers were not breastfeeding. Find out or suggest how they could still be a part of the trial.
   e. Suggest how Dr Smithers may have decided which mothers received DHA and which did not. How would you have decided? Why?
   f. Discuss issues related to the decision of who gets the 'test drug/chemical' and who doesn't. If you had the choice, which group would you like to be in? Are there any other factors that may change your response? Discuss and explain.
   g. State what the findings of this research suggested.
   h. Suggest a myth that could result from this research.
7. *Not all chocolate is created equal.* Suggest what this statement may mean and how it could relate to the myths and truths about the benefits of eating chocolate.

Fully worked solutions and sample responses are available in your digital formats.

3.7 Drugs on your brain

LEARNING INTENTION

At the end of this subtopic you will be able to describe the different ways that drugs affect your body.

3.7.1 How drugs affect your brain

Popping a pill or taking something that you shouldn't? Are you aware of the short- and long-term effects of your actions?

Introducing various chemicals into your body can have both beneficial and terrifying consequences. After all, we all need to eat and drink to obtain our nutrients. But there are some chemicals that can cause you great damage.

Neurotransmitters

Neurotransmitters are key players in our memory, learning, mood, behaviour, sleep and pain perception. These chemicals pass a message from one neuron (pre-synaptic neuron) to another (post-synaptic neuron) across a gap between them called a synapse.

Although there are many different neurotransmitters, only one is used at each synapse. The type of neurotransmitter that is released at the synapse can be used to classify them into groups. For example, in your brain some synapses release acetylcholine, whereas others may release noradrenaline, dopamine or enkephalins. The effect that these neurotransmitters have depends on the type of receptor that is present on the membrane of the neuron that receives it. Once the message has been received, enzymes break the neurotransmitter down.

Neurotransmitters carry the message from one neuron to the next. They are stored in sacs called vesicles. When neurotransmitters are released from the vesicles of one neuron, they travel across the synapse to bind to specific receptors on the membrane of the next neuron.

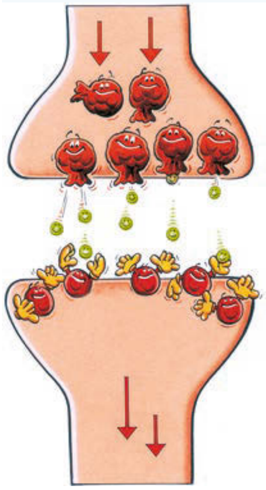
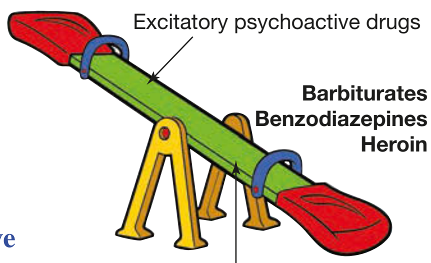


FIGURE 3.45 Neurotransmitters pass messages across a synapse

3.7.2 Psychoactive drugs

Some drugs can affect your brain or personality by either increasing or decreasing transmission of messages across the synapse. These are collectively known as **psychoactive drugs**. These drugs can bind to the receptors, mimic the neurotransmitter or block the binding of the neurotransmitter to its receptor. Nicotine is an example of a drug that mimics the working of acetylcholine.

FIGURE 3.46 Examples of excitatory psychoactive drugs and inhibitory psychoactive drugs



Some examples of **excitatory psychoactive drugs** include nicotine, caffeine, cocaine and amphetamines ('speed'). Many of these drugs come from natural sources. They all stimulate or increase the synaptic transmission. Like many other drugs of abuse, these stimulants activate your brain's reward circuit. Excitatory psychoactive drugs can be thought of as **stimulants** or 'uppers'.

psychoactive drugs chemicals that decrease synaptic transmission (such as barbiturates) or increase synaptic transmission (such as caffeine)

excitatory psychoactive drugs chemicals such as caffeine that increase or stimulate synaptic transmission

stimulants excitatory psychoactive drugs, such as caffeine and amphetamines, that increase or stimulate synaptic transmission

inhibitory psychoactive drugs chemicals, such as barbiturates, that decrease synaptic transmission

depressants inhibitory psychoactive drugs that reduce or decrease synaptic transmission

caffeine an excitatory psychoactive drug that stimulates or increases synaptic transmission

Inhibitory psychoactive drugs can be considered as **depressants** or 'downers'. As their name implies, they work by inhibiting or decreasing synaptic transmission. Barbiturates, benzodiazepines (such as Valium), alcohol and cannabis (marijuana) are examples of drugs that decrease the activity of your nervous system.

3.7.3 Uppers or excitatory psychoactive drugs

Caffeine

What do coffee, tea, cocoa, chocolate and some soft drinks have in common? They all contain **caffeine**. In moderate doses, this central nervous system stimulant can increase alertness, reduce fine motor coordination, and cause insomnia, headaches, nervousness and dizziness. In massive doses it is lethal.

One effect of caffeine is to interfere with adenosine at multiple sites in your brain, but this drug also acts on other parts of your body. It increases your heart rate and urine production.

TABLE 3.2 Levels of caffeine in common foods

Substance	Quantity of caffeine (mg)
Filter coffee (200 mL)	140
Instant coffee (200 mL)	80
Tea (200 mL)	80
Dark chocolate (30 g)	35
Typical cola (330 mL)	32
Milk chocolate (30 g)	15
An adult's average daily consumption of caffeine is about 280 mg. A fatal dose is about 10 g.	

FIGURE 3.47 Milk chocolate contains low levels of caffeine.

Cocaine

Cocaine (coke, snow, crack, gold dust or rock) works by inhibiting or blocking the uptake of neurotransmitters — dopamine, norepinephrine or serotonin — in a synapse, prolonging effects within the central nervous system. This results in elevated heart rate and body temperature, increased alertness and movement, and dilation of pupils. High levels of norepinephrine may result in strokes, organ failure and heart attacks.

FIGURE 3.48 Large doses of cocaine can cause heart attacks, strokes, paranoia and hallucinations.

Amphetamines

Amphetamines (speed, ice, ecstasy, meth, pep pills or fast) are synthetic chemicals that affect levels of neurotransmitters — dopamine, norepinephrine or serotonin. Long-term use can result in insomnia, hallucinations, tremors, and violent and aggressive behaviour. Some amphetamines are **neurotoxic** and cause neuron death.

Ecstasy or MDMA is distributed in small tablets, capsules or powder form. Short-term effects include increased blood pressure, body temperature and heart rate. Larger doses can result in convulsions, vomiting and hallucinations. There is also a risk of heart attack or brain haemorrhage and swelling, and there is evidence that it causes long-term damage to the neurons in your brain.

FIGURE 3.49 While the short-term effects may be a dry mouth, enlarged pupils, headaches and increased confidence, frequent use of amphetamines may result in psychosis.

3.7.4 Downers or inhibitory psychoactive drugs

Barbiturates

Barbiturates are often taken to calm someone down and are used as sedatives. Sleeping pills are one such example. One key problem is that they may lead to tolerance and dependence. A key danger associated with barbiturates is that there is only a small difference between a dose that produces sedation and one that may cause death.

cocaine an example of an excitatory psychoactive drug that stimulates or increases synaptic transmission

amphetamines nervous system stimulants, such as 'speed'

neurotoxic leads to the death of neurons

ecstasy an example of an excitatory psychoactive drug; a synthetic hallucinogenic drug (methylenedioxymethamphetamine, MDMA)

barbiturates chemicals that inhibit or decrease synaptic transmission and are hence depressants. They are often taken to calm people down and are used as sedatives.

Marijuana

In 1964, the psychoactive ingredient in **marijuana** (also known as grass, pot, reefer or weed) was identified as a **THC** (delta-9 tetrahydrocannabinol). This chemical comes from a plant called *Cannabis sativa*. THC activates cannabinoid receptors in your brain located on neurons in your hippocampus (memory), cerebral cortex (concentration), sensory portions of your cerebral cortex (perception) and your cerebellum (movement). High doses of this drug may cause hallucinations, delusions, impaired memory and disorientation. As it is one of the world's most commonly used illegal drugs, there has been a great deal of research into how it works and the consequences of using it. In recent years, it has been approved for medicinal use, most commonly for chronic pain relief, and is now grown commercially for this purpose (figure 3.50).

FIGURE 3.50 Medicinal cannabis growth operation

GHB

GHB (gamma hydroxybutyrate, sodium oxybate, also known as liquid E, fantasy or gamma-OH) is an odourless, colourless, salty liquid that acts as a depressant on your nervous system. One of the dangers of this drug is the difficulty of determining a safe dosage. Although a small amount may have a euphoric effect, more can lead to amnesia, respiratory difficulties, delirium, loss of consciousness and possibly death. Likewise, combining GHB with alcohol can also lead to deep unconsciousness and may cause coma or death. GHB also has the reputation of being used as a 'date-rape' drug.

Heroin

Diacetylmorphine or **heroin** (also known as smack, jive, horse or junk) is an illegal opiate drug that contains morphine as its active ingredient. Its source is the opium poppy, *Papaver somniferum*. **Opiates** stimulate a pleasure system in your brain that involves the neurotransmitter dopamine.

In 1973, scientists found neurons in the brain that have receptors for opiates. These are located in areas involved in pain, breathing and emotions. The discovery of these receptors led to further research about their purpose. Two years later, scientists discovered that the brain manufactures its own opiates known as **endorphins**. Although endorphins are always present in the brain, when you are in pain or stressed they are released in larger amounts.

marijuana plant in which the active ingredient is an inhibitory psychoactive drug that reduces or decreases synaptic transmission; sometimes called cannabis

THC the active ingredient in marijuana; also known as delta-9 tetrahydrocannobinol

GHB gamma hydroxybuturate, also known as liquid E or fantasy, which depresses the nervous system

heroin an inhibitory psychoactive drug that decreases synaptic transmission

opiates drugs derived from the opium poppy that involve the neurotransmitter dopamine in stimulating pleasure centres in the brain; they may also induce sleep and alleviate pain

endorphins hormones resembling opiates that are released by the brain when you are in pain, in danger or under other forms of stress

3.7.5 Alcohol

Unlike water, some drinks can have a negative effect on your health. One such drink is **alcohol**.

Alcohol is a depressant and can alter your mood, thinking and behaviour. Many parts of your body are affected by alcohol.

Alcohol and the digestive system

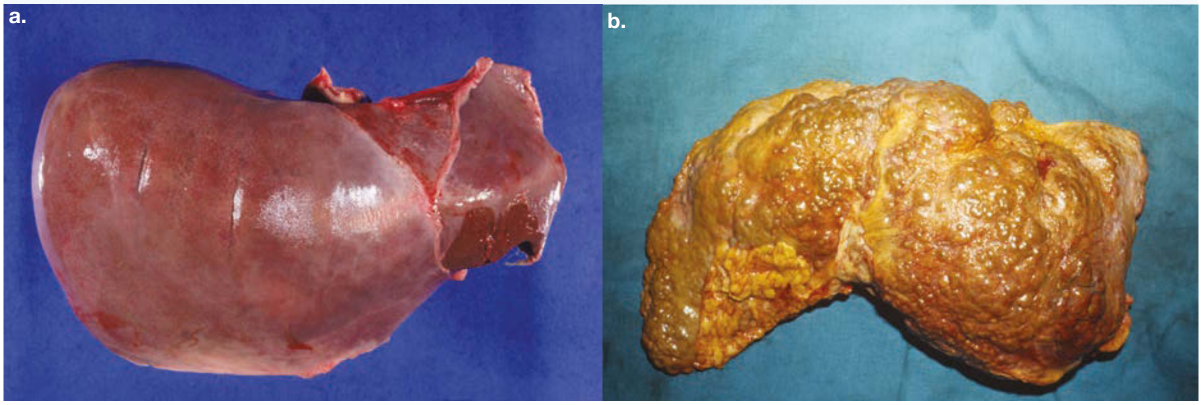
Alcohol is a substance that is directly absorbed into your bloodstream through your stomach and small intestine. It irritates your stomach and causes more stomach acid to be produced, which can result in painful heartburn and stomach ulcers. Alcohol is also linked to mouth, oesophagus, stomach and intestinal cancers.

The part of the digestive system that is affected most is the liver. Alcohol can destroy liver cells and can cause fat to accumulate around the liver, resulting in a fatal condition known as cirrhosis (figure 3.52).

alcohol a colourless volatile flammable liquid (such as ethanol, C_2H_5OH) that is made by fermentation of sugars and starches

FIGURE 3.51 Alcohol affects all parts of your body.

FIGURE 3.52 a. A healthy liver and b. a liver from a person with cirrhosis caused by excess alcohol consumption. Alcohol is an example of a toxin broken down by the liver — excess consumption of alcohol can cause extra strain on liver tissue and damage to liver cells.



Alcohol and the brain

Did you know that alcohol slows down your brain activity by interfering with your cerebellum? This may affect your coordination and perception and cause memory blackouts. When alcohol reaches your midbrain, your reflexes diminish, confusion and stupor follow, and then you may lapse into a coma. When the alcohol reaches your medulla, your heart rate may drop and your breathing may stop, possibly resulting in death.

Some common questions about alcohol

Does eating food stop you from getting drunk?

The rate at which alcohol is absorbed may be slowed by the presence of food in your stomach but it won't prevent you getting drunk or intoxicated.

How can you sober up more quickly?

Your liver works at a fixed rate. It will detoxify or clear about one standard drink each hour (see the standard drinks guide opposite). So, black coffee, cold showers, fresh air and vomiting won't speed up the process of getting rid of alcohol from your body.

Should pregnant women drink alcohol?

During the first three months of pregnancy, alcohol interferes with the migration and organisation of brain cells. Heavy drinking during the next trimester, particularly between 10 and 20 weeks after conception, can have the biggest impact on the baby, leading to foetal alcohol syndrome (FAS). Drinking during the last trimester may affect the baby's hippocampus, which may reduce the child's future ability to encode visual and auditory information (reading and maths).

FIGURE 3.53 Heavy drinking during pregnancy can damage the baby's brain.

Australia and alcohol

Headlines in Australian news stories increasingly relate alcohol abuse to accidents or violence that result in injury or death. There are data to suggest that drinking at dangerous levels is increasing within our culture.

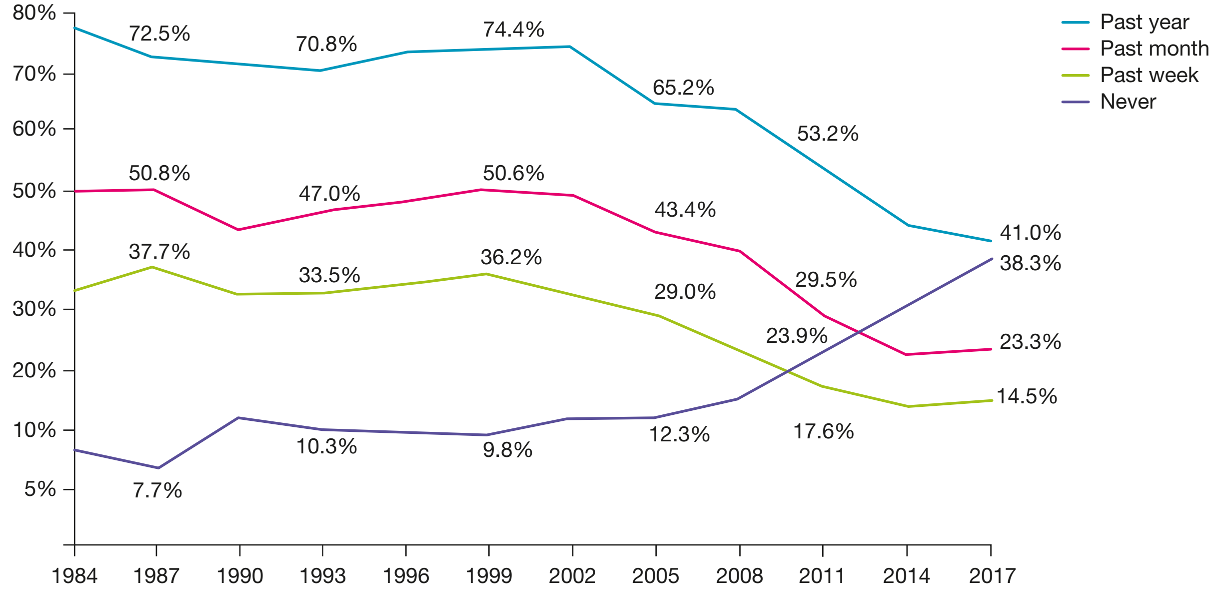
Over the last decade, there has also been an increase in the number of women drinking at risky or high levels. This has implications not just for the woman and those close to her, but potentially to the health of an unborn child.

While some Australians believe that they have a right to drink and eat whatever, whenever and however they wish, the government is not of the same belief. There are already restrictions on the amount of alcohol in your blood when you are driving and in a number of public places the consumption of alcohol is illegal. With increasing evidence of the dangers of alcohol not just to ourselves but also to others, where will the line be drawn and how will it be implemented?

FIGURE 3.54 A standard drink contains about 10 grams of alcohol. It takes the liver about an hour to break down the alcohol in one standard drink.

The graph in figure 3.55 shows the prevalence (how many people, the percentages) and the recency of alcohol use for students in Western Australia (WA) aged 12–17, from 1984 to 2017. The recency is a recording of when alcohol was consumed — in the past week, month, year, or if alcohol has never been drunk.

FIGURE 3.55 The recency and prevalence of alcohol consumption in WA students aged 12–17 years old



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3.7 Exercise

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To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. State the name of the gap across which neurotransmitters pass.
2. List three examples of neurotransmitters.
3. What do the vesicles in neurons contain?
4. What are psychoactive drugs?
5. State other names for:
   a. inhibitory psychoactive drugs
   b. excitatory psychoactive drugs.
6. What is the key difference between excitatory and inhibitory psychoactive drugs?
7. What is meant by the term *neurotoxic*?

Apply and analyse

8. Which type of alcoholic drink in the standard drinks guide has the:
   a. most alcohol
   b. least alcohol?
9. How many standard drinks are there in a 750 mL bottle of wine?

Evaluate and create

10. Use a flow chart to show the links between a pre-synaptic neuron, a neurotransmitter and a post-synaptic neuron.
11. Use a cluster map to show examples of the effects of the following drugs.
    a. Caffeine
    b. Cocaine
    c. GHB
    d. Heroin
    e. Ecstasy
12. SIS Consider the graph at figure 3.55. Compare the percentage of students who have never drunk alcohol in 1984, compared to 2017. Suggest reasons for the variation.

Fully worked solutions and sample responses are available in your digital formats.

3.8 Organ transplants and stem cells

LEARNING INTENTION

At the end of this subtopic you will be able to explain scientific developments that help the body function, including organ transplants and stem cell research.

3.8.1 Organ transplants

Organs within your body systems play an important role in keeping you healthy — and alive. But what if one of them fails? What if an organ with a critically important function could no longer do its job and needed to be replaced?

There are some organs that you just cannot live without. For example, if you didn't have a heart, what would pump the blood around your body? Without lungs, how could you obtain the oxygen that you need and remove the carbon dioxide that you don't?

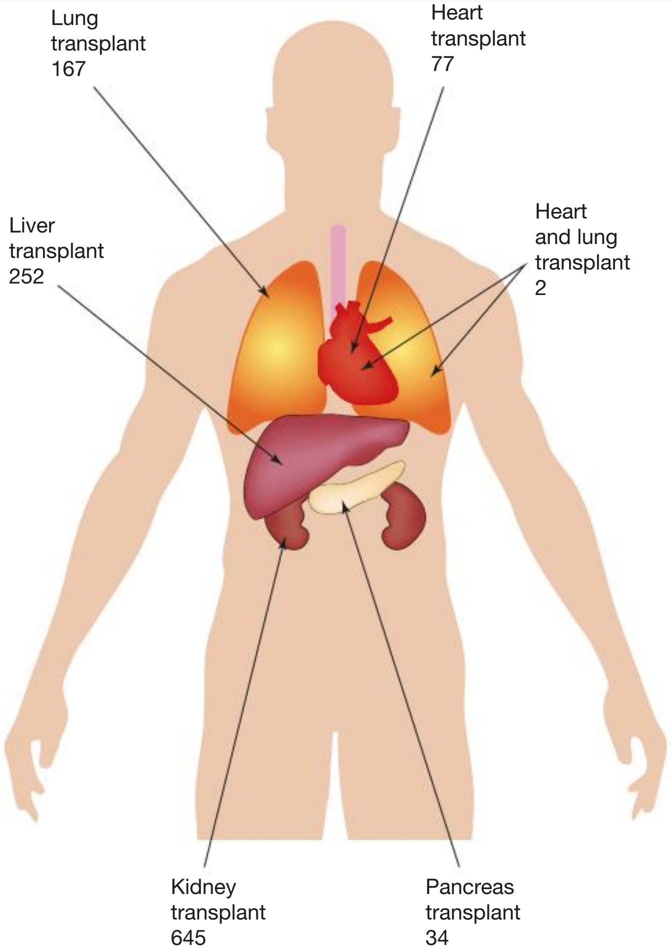
Scientists and researchers around the world have been developing and performing amazing operations to replace failed organs in the body. A solution to having a faulty organ is to replace it with another one that works. This may be achieved by transplanting a healthy organ from another person. In many cases, the source of the replacement organ is a recently deceased person. Organ transplantation presents a variety of medical challenges and raises a number of ethical issues.

Waiting in line for an organ …

There is a shortage of organs for transplantation and, depending on the organ, there are usually long waiting lists and times. Most essential organs cannot be obtained from live donors. Kidneys are an exception. As you have two kidneys and can live with only one, one of these can be donated while you are alive.

Patients who are on life support in hospitals are also a source of some organs for transplantation. These patients may have no brain function, or very limited, if any, chance of recovery. Another source of organs may be those from people in car accidents. When applying for a driver's licence, some people register as a donor, so that their organs may be transplanted into others when they die. In Australia you have to be 18 years old before you can register as an organ donor but people aged 16 or 17 can register their interest.

FIGURE 3.56 Number of transplants performed in Australia in 2019



Is it a match?

Even when an organ becomes available for transplant, it needs to match the recipient's blood type and have a reduced chance of being rejected by the recipient's immune system. There needs to be a matching of special proteins called **antigens** between the donor and the recipient. Even so, the recipient's immune system will still attack the transplanted organ as a foreign 'non-self' invader, so drugs are required to suppress this response.

Growing body parts in labs

Researchers are investigating the construction of skin, cartilage, heart valves, breast, ears and other body tissues in tissue-engineering laboratories. Some of these technologies involve injection of synthetic proteins to induce tissues to grow and change; some use scaffolding techniques; and some even use 3D printers to print out tissues such as blood vessel networks.

antigens substance that stimulates the production of antibodies

CASE STUDY: Growing hearts

Cardiac researcher Doris Taylor has revived the dead. The process involved rinsing rat hearts with a detergent solution to strip the cells, until all that remained was a protein skeleton of translucent tissue — a 'ghost heart'. She then injected this scaffold with fresh heart cells from newborn rats and waited. Four days later, she saw little areas beginning to beat. After eight days, the whole heart was beating. Could this research lead to new transplant technologies for use in humans?

FIGURE 3.57 Doris Taylor and her team of researchers

3.8.2 Stem cells

Stem cells are also being investigated as a possible solution to the shortage of donor organs.

Stem cells are unspecialised cells that can reproduce themselves indefinitely. Stem cells are categorised in terms of:

- their source — **embryonic stem cells** from embryos or **somatic stem cells** from adults or umbilical cord blood (figure 3.58)
- their ability to differentiate into many different and specialised cell types (figure 3.59).

Stem cells in a fertilised egg are **totipotent** — they have the ability to differentiate into *any* type of cell.

The ability to differentiate into specific cell types makes stem cells invaluable in the treatment and possible cure of a variety of diseases. For example, they may be used to replace faulty, diseased or dead cells. The versatility of stem cells is what makes them very important.

embryonic stem cells stem cells derived from the inner cell mass of a blastocyst. These cells are pluripotent and can give rise to most cell types.

somatic stem cells undifferentiated multipotent cells that are found in adults and umbilical cord blood; they can generate only certain types of cells

totipotent the most powerful stem cells that can differentiate into all cell types

FIGURE 3.58 Stem cells can be described in terms of their source.

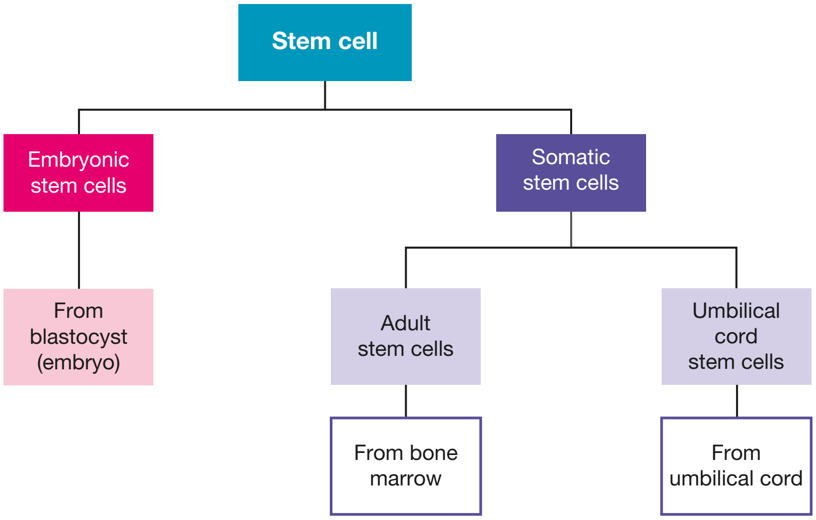
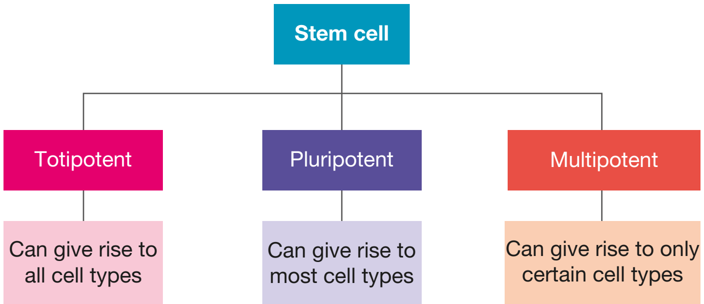


FIGURE 3.59 Stem cells can be divided into categories on the basis of their ability to produce different cell types.



Sources of stem cells

Embryonic stem cells can be obtained from the inner cell mass of a **blastocyst**. The blastocyst is the term used to describe the mass of cells formed at an early stage (5–7 days) of an embryo's development. Embryonic stem cells are **pluripotent** and can give rise to most cell types; for example, blood cells, skin cells, nerve cells and liver cells.

blastocyst a cluster of cells formed in early stages of mammal embryo development, containing an inner cell mass

pluripotent stem cells that can differentiate into most cell types; for example, blood cells, skin cells and liver cells

FIGURE 3.60 An embryo is the result of a sperm fertilising an egg. If this happens outside a woman's body, it is called in-vitro fertilisation.

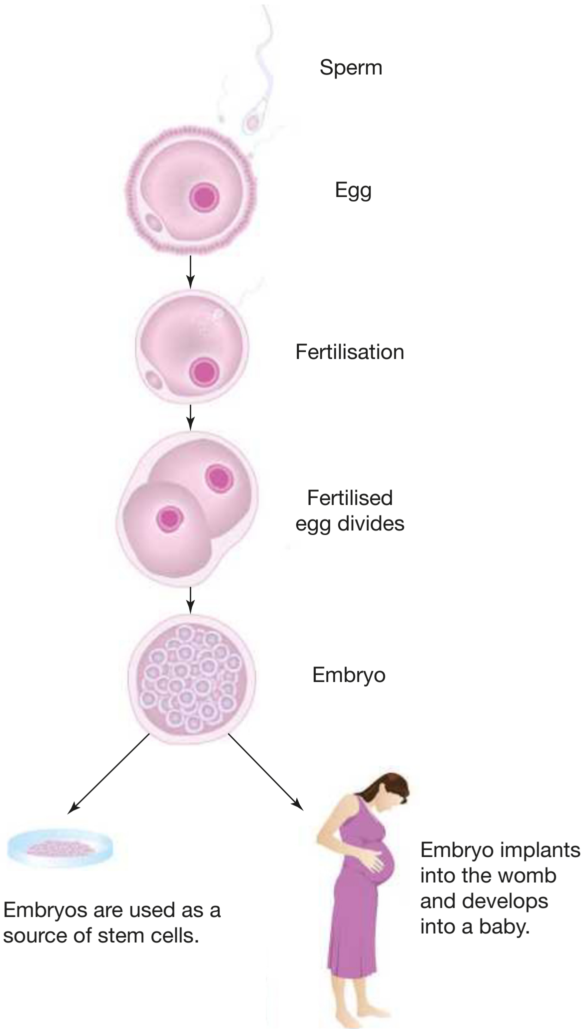
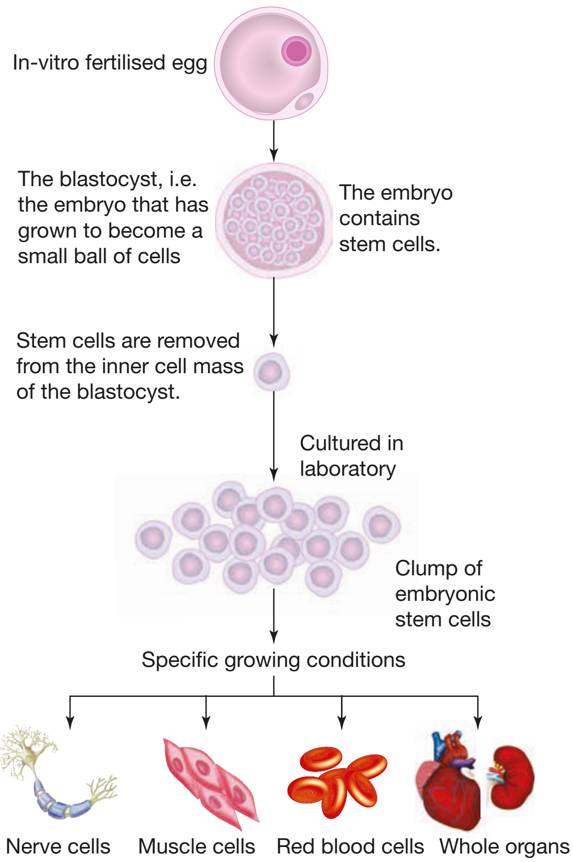


FIGURE 3.61 Embryonic stem cells are removed from the blastocyst and cultured to produce different cell types.

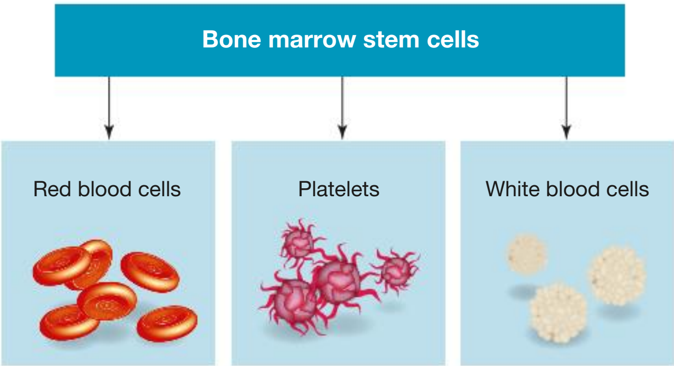


Somatic stem cells can be obtained from bone marrow and umbilical cord blood and are **multipotent**. They can differentiate into only a few cell types. Stem cells obtained from the bone marrow are often referred to as adult stem cells and can develop into different kinds of blood cells.

multipotent stem cells that can differentiate into only a few cell types

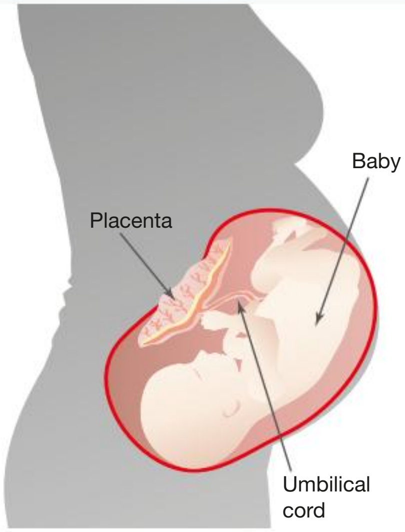
umbilical cord stem cells stem cells that can develop into a few types of cells (mainly blood cells and cells involved in fighting disease) and are also being used to treat leukaemia and other blood disorders

FIGURE 3.62 Bone marrow somatic stem cells can differentiate into different kinds of blood cells.



The umbilical cord is the cord that connects the unborn baby to the placenta. This is how the baby gets nutrients and oxygen while it is still inside the mother's body. This cord contains stem cells that can develop into only a few types of cells, such as blood cells and cells useful in fighting disease. **Umbilical cord stem cells** can be taken from this cord when the baby is born.

FIGURE 3.63 Umbilical cord stem cells can be collected when a baby is born.



Using stem cells

While the information in your genetic instructions tells your cells which types of cells they should become, scientists have also been able to modify the 'future' of some types of cells. By controlling the conditions in which embryonic stem cells are grown, scientists can either keep them unspecialised or encourage them to differentiate into a specific type of cell. This provides opportunities to grow replacement nerve cells for people who have damaged or diseased nerves. Imagine being able to cure paralysis or spinal cord injury. In the future, stem cells may also be used to treat and cure Alzheimer's disease, motor neurone disease, Parkinson's disease, diabetes and arthritis.

Bioethical considerations

Use of stem cells in Australia is highly regulated by a number of Federal and State and Territory Acts and guidelines and standards issued by the Australian Health Ethics Committee. Embryonic stem cells can only be taken from spare human embryos that are left over from fertility treatments or from embryos that have been cloned in the laboratory.

Some argue that this artificial creation of an embryo solely for the purpose of obtaining stem cells is unethical because the embryo is destroyed during the process of obtaining stem cells. It is illegal to clone a human embryo in Australia for the purpose of reproduction.

In rare cases, parents who have a child with a serious disease may decide to have another child for the purpose of being able to provide stem cells. In this case, the blood from the umbilical cord or placenta is used as the source. The ethics of such a decision must be carefully contemplated, to ensure the rights of the potential second child are considered.

CASE STUDY: Stem cell therapy a world first

By Michelle Pountney, health reporter

A MELBOURNE man is the first person in the world whose own stem cells are being used to try to mend a broken leg.

The cutting-edge stem-cell technology has helped Jamie Stevens, 21, back on his feet.

A motorcycle crash nine months ago left him with a severely broken left thigh bone. Part of the femur stuck through his leg, and other parts of the bone were missing.

The bone failed to heal and Mr Stevens's leg was held together by a large titanium plate.

Royal Melbourne Hospital orthopedics director Richard de Steiger decided Mr Stevens was the ideal first patient for a revolutionary stem-cell trial at the hospital.

About seven weeks ago, Mr de Steiger harvested bone marrow from Mr Stevens' pelvis. The adult stem cells were then separated from the other cells. A sub-group of stem cells called mesenchymal precursor cells — those that can transform into tissues including bone cartilage and heart — were isolated and grown.

Last week about 30 million of these cells were implanted into the 5 cm × 3 cm hole in Mr Stevens' thigh bone. The cells are expected to regenerate new bone and grow through the calcium phosphate.

Yesterday, just four days after surgery, Mr Stevens went home.

'It's good to be part of something that is on the brink,' he said. 'I wouldn't say I understand it. It's all pretty cool.'

FIGURE 3.64 Jamie Stevens prepares to leave Royal Melbourne Hospital with his surgeon Richard de Steiger. If there are too many arguments about using someone else's stem cells, why not grow your own to mend, replace and renew?

It will be three to four months before the result of the operation is known.

'This is radical and the first procedure in the world to use a patient's own stem cells and make them turn into bone-forming cells that are the patient's own cells, to stimulate healing of a fracture,' Mr de Steiger said.

The cells are harvested, cultured and expanded using Australian biotechnology company Mesoblast's specialist adult stem-cell technology.

Mr de Steiger hopes that eventually the technique will be refined to a simple injection, avoiding further surgery.

Using a patient's own cells avoids the potential problem of the body's rejection of foreign cells.

The only other alternative to repair Mr Stevens' leg would have been a painful bone graft, taking a chunk of bone from his hip and plugging it into the hole in his thigh.

'The conventional way used over many years involves a large incision at the pelvis and taking out quite a large amount of bone in Jamie's case,' Mr de Steiger said.

'In this situation there is the risk of a separate incision, reported continuing pain from that incision, and separate infection risk at that site.'

Mr de Steiger said orthopedic specialists at the Royal Melbourne hospital treated about 200 fractures of the long leg bones each year.

About 19 per cent become 'non-union' fractures that fail to heal; 10 of these patients will be recruited to be part of the year-long trial.

Mr Stevens said he was no more nervous about being the first patient in the world to have the procedure than he would have been having a graft.

'I think the benefit outweighs the old procedure, and being able to avoid having a big chunk of bone taken out of the hip . . . the recovery period of it was a lot quicker.'

After living in limbo for nine months, Mr Stevens said he was looking forward to resuming the life he enjoyed before his accident.

CASE STUDY: Leading Australian scientist — Alan Trounson

Professor Alan Trounson is an Australian scientist who has spent a great part of his working life perfecting the technique for creating embryos outside the human body. He was part of the team that produced the first test-tube baby in Australia in 1980. He has also done a lot of work on embryonic stem cells. In 2000, his team showed that it was possible to produce nerve cells from embryonic stem cells, which meant that stem cells could potentially be used to cure diseases that have up to now been incurable. This has led to a surge of interest in the field of stem cell research.

In 2003, he was named the Australian Humanist of the Year. Between 2007 and 2014, he was appointed as the president of the California Institute for Regenerative Medicine, which specialises in stem cell research. He is now an Emeritus Professor of Melbourne University.

FIGURE 3.65 Alan Trounson

ACTIVITY: What's your stance on organ transplants?

The aim of this activity is to analyse the attitudes and opinions of your classmates on organ transplants. You will need to critically evaluate the ethics of organ transplants and their availability to patients.

Choose one of the following statements:
- It should be legal to buy transplant organs from either a live donor or from the family of a deceased donor in Australia.
- Animals such as pigs should be used to grow organs for human transplants.
- The creation of human embryos for stem cell research in Australia is acceptable.
- Doctors should be allowed to harvest the organs of a deceased patient for organ transplants without the permission of the patient's relatives.
- It should be compulsory for all Australians over the age of 18 to sign the donor register.
- Smokers, heavy drinkers and drug users should be further down the organ transplant waiting list than those with a healthy lifestyle.

1. Construct a PMI chart for the statement.
2. Do you agree with the statement?
3. In the classroom, construct a human graph to show people's opinions about the statement. Stand in positions to indicate your feelings about the statement. For example:
   - Strongly disagree (0): stand next to the left-hand wall
   - Agree (2): stand in the centre of the room
   - Strongly agree (4): stand next to the right-hand wall
4. Have a discussion with students standing near you to find out the reasons for their opinion.
5. Listen to the discussions of students in other positions.
6. Construct a SWOT diagram to summarise what you have found out.
7. Record the results of the human graph and examine them to answer the questions in your discussion.
8. **a.** What was the most popular attitude? Suggest a reason for this.
   b. What was the least popular attitude? Suggest a reason for this.
   c. Do you think this attitude pattern is representative of other Australians your age? Explain.
9. On the basis of your discussion, have you changed your attitude since the start of this activity? If so, how is it different and why?

on Resources

assesson Additional automatically marked question sets

3.8 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Fill in the blanks to complete the sentences.
   Stem cells are __________ cells that can _________ themselves indefinitely and have the ability to ______________ into many different and _______________ cell types. Stem cells are important for growth and repair as they can differentiate into specific cell types.
2. MC Identify the source of embryonic stem cells.
   A. Blastocyst **B.** Bone **C.** Bone marrow **D.** Umbilical cord
3. MC Which kinds of cells can bone marrow stem cells develop into?
   A. Muscle cells **B.** Nerve cells **C.** Red blood cells **D.** All of the above
4. What type of stem cells can be obtained from bone marrow and umbilical cord blood?
5. Identify the name of the special proteins that need to be matched between the transplant donor and the recipient.
6. Distinguish between the terms 'totipotent', 'pluripotent' and 'multipotent'.

Apply and analyse

7. What are stem cells? Outline the importance of stem cells.
8. What are the two main types of stem cells and describe their source.

Evaluate and create

9. Outline issues regarding stem cell research.
10. Investigate some of the following questions.
    a. Identify an inherited genetic disease that is potentially treatable with stem cells?
    b. Where can adult stem cells be sourced?
    c. Why have the adult stem cells remained undifferentiated?

Fully worked solutions and sample responses are available in your digital formats.

3.9 Thinking tools — Priority grids and matrixes

3.9.1 Tell me

What is a priority grid?

A priority grid can help you prioritise or rank ideas, choices or activities in order. It can help you make decisions by showing the positives and negatives or how important each of the various ideas, choices or activities are, compared to how difficult or easy they are to finish. It can help you work out what is the best option to follow and why. It can also allow you to compare your views and judgements with others.

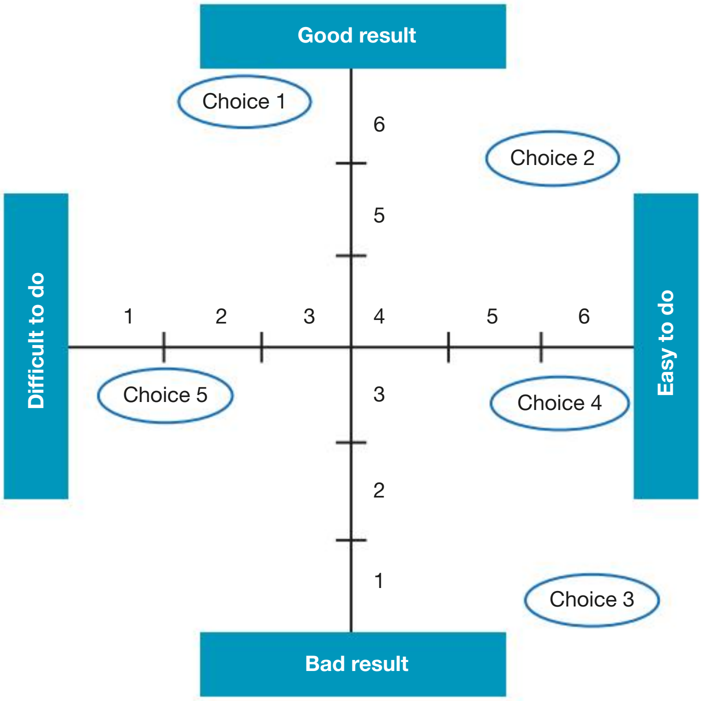
A priority grid is divided vertically and horizontally, which divides the grid into quarters.

- The vertical is used to rate the task. This could be, for example, whether it is a good result or a bad result, or if it is important or not important.
- The horizontal is used to rate whether it is difficult or easy to finish, or if the task is urgent or not urgent

This allows the tasks to be ranked in order of priority.

A priority grid is also called a priorities grid or a decision grid.

FIGURE 3.66 Priority grid



What is a matrix?

A matrix also shows the positives and negatives of a topic. But it is used to compare between different topics or activities. It does not rank them as easy or difficult. It is used to compare features of different topics or activities.

FIGURE 3.67 Matrix

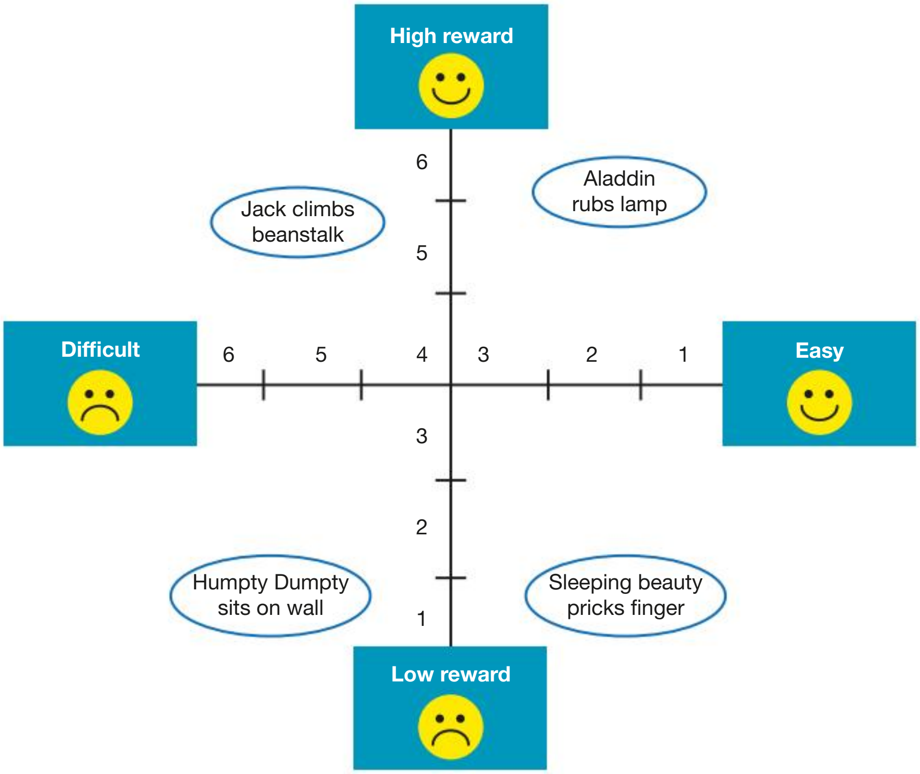
Topic	Feature A	Feature B	Feature C	Feature D	Feature E
1	✓		✓	✓	✓
2		✓			✓
3		✓		✓	✓

3.9.2 Show me

How to create a priority grid.

1. Draw two continuums that cross through each other at right angles.
2. Divide each line into six equal parts.
3. Put a label like 'difficult' on the left end of the horizontal line and 'easy' on the right.
4. Put a label like 'high reward' at the top of the vertical lines and 'low reward' at the bottom.
5. Think of an activity and assess it using these two lines, placing a mark where you think it fits best.
6. Compare and discuss your marked positions with those of others in your class. Share your ideas, values, views and judgements, and listen to those of others.
7. After your discussions and reflections, write your final positions directly onto the grid.
   You might use a priority grid to compare the outcome of different nursery rhymes.

FIGURE 3.68 Priority grid of nursery rhymes



3.9.3 Let me do it

3.9 ACTIVITIES

1. **a.** Use a priority grid to evaluate some of the foods shown in figure 3.69.
   b. Describe the criteria that you used to make your decisions.
   c. In a team, brainstorm criteria that could be used to assist you in placing other foods on a priority grid. As a team, agree on your criteria.
   d. Construct a matrix with the agreed criteria in the first column and a variety of foods across the top row.
   e. Score each of the foods using your criteria, entering your results in the table.
   f. Use the data in your matrix to help you place these foods on a second priority grid.
   g. If you have any areas on the priority grid empty, suggest foods that may fit there. Share your reasoning with your team.
   h. Share and discuss your team grid with those of other classmates.

FIGURE 3.69 Different types of food

Fully worked solutions and sample responses are available in your digital formats.

3.10 Review

Access your topic review eWorkbooks

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-4775	ewbk-4777	ewbk-4779

on Resources

3.10.1 Summary

Respiratory and circulatory systems

- Multicellular organisms contain co-ordinated and interdependent systems that perform particular jobs within the body.
- Systems are made up of a variety of organs, that in turn consist of many tissues that in turn are composed of millions of cells.
- The main role of the respiratory system is to take oxygen into your body and carbon dioxide out.
- Organs of the respiratory system include the nose, trachea and lungs, which are made up of bronchi, bronchioles and alveoli.
- Cellular respiration is the breakdown of food in the presence of oxygen to produce energy in a form cells can use.

$$\text{Glucose} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water} + \text{energy}$$

- Gases in the blood are exchanged in the alveoli, which are only one cell thick.
- Oxygen moves from the alveoli into the red blood cells in the surrounding capillaries and binds to the haemoglobin to form oxyhaemoglobin. This is known as oxygenated blood.
- Carbon dioxide diffuses out of the cell and into the capillary. This is deoxygenated blood.
- The circulatory system transports oxygen and nutrients to your body's cells and to remove wastes, like carbon dioxide away.
- Organs in the circulatory system include the blood, blood vessels (veins, arteries and capillaries) and the heart.
- Arteries transport oxygenated blood away from the heart to the body tissues. Their walls are rigid, thicker and muscular.
- Veins carry deoxygenated blood from body tissues to the heart. Their walls are thin and collapsible and contain valves so that blood does not flow backwards.
- Oxygenated blood moves through the body via the pulmonary vein to the left atrium of the heart, to the left ventricle, to aorta, to arterioles, to capillary, to the body cells.
- Deoxygenated blood flows back into the capillary to the venules, to vena cava, to right atrium of the heart, to the right ventricle of the heart, to the pulmonary artery and finally expelled.

Essential intake

- Nutrients are substances needed for energy, cell functioning and for your body's growth and repair.
- The nutrients that are essential for a healthy body are carbohydrates, proteins, lipids, vitamins and minerals.
  - carbohydrates — provide a source of energy. Found in grains, starchy vegetables, bread.
  - proteins — used for cell growth and repair of damaged tissues, produce enzymes and hormones. Found in meat, poultry, eggs, legumes, nuts.
  - lipids — source of energy. Found in oils and fats.
  - vitamins and minerals — needed in small amounts and speed up and control chemical reactions in the body. Found in numerous foods especially fruit and vegetables.

- Nutrients also make neurotransmitters that can affect your emotions. These include tryptophan and serotonin.
- Water and fibre are also essential for good health. They are known as essential non-nutrients.

Digestive and excretory systems

- The main role of your digestive system is to supply your body with the nutrients it requires to function effectively.
  - Physical digestion is the mechanical breakdown of food. It begins in the mouth as food is chewed.
  - Chemical digestion is when food is broken down further into simpler compounds or nutrients by enzymes and used by cells.
- Organs of the digestive system: mouth, oesophagus, stomach, small intestine, large intestine, rectum, anus.
- Other important organs involved in the digestive system are: pancreas, liver and gallbladder.
- The three main types of enzymes are:
  - amylase that digest carbohydrates
  - protease that digest protein
  - lipase that digest fats/lipids.
- The excretory system removes waste products of a variety of necessary chemical reactions.
- Organs involved in the excretory system are: skin, kidneys, liver and lungs.
  - The kidneys are involved in excreting the unused waste products of chemical reactions (for example, urea) and any other chemicals that may be in excess (including water) so that a balance within our blood is maintained.
  - The liver is involved in breaking down toxins for excretion.
- Dehydration occurs to the body when we lose too much water.
- Constipation occurs when there is difficulty in releasing solid waste from the body due to insufficient water or fibre in the diet.

Living warehouses

- To function effectively, your body needs energy (glucose that is obtained from the foods we eat).
- Blood glucose levels in the body are regulated by hormones — too high and the pancreas releases insulin in the body, too low and the pancreas releases glucagon.
- Diabetes occurs when the glucose levels become too high in the body.
- The glycaemic index of food is a measure of the time it takes for your blood sugar levels to rise after you have eaten.
  - Low glycaemic foods are rich in fibre and digested slowly; for example, wholemeal breads, lentils, peanuts.
  - High glycaemic foods contain starch and sugar and are digested easily; for example, rice, white bread, honey.
- Obesity is where the body stores an excessive amount of body fat.

Myths, moods and foods

- Some foods can not only affect us physically, but mentally too by having an effect on our moods; for example, dark chocolate, caffeine, junk foods.

Drugs on your brain

- Various drugs can have an effect on the neurotransmitters in our body.
- Psychoactive drugs can affect your brain or personality by either increasing or decreasing transmission of messages across the synapse.
- Excitatory psychoactive drugs all stimulate or increase the synaptic transmission; for example, nicotine, caffeine, cocaine. They are also known as stimulants.
- Inhibitory psychoactive drugs work by inhibiting or decreasing synaptic transmission. These include barbiturates, benzodiazepines (such as Valium), alcohol and cannabis (marijuana). They are also known as depressants.
- Alcohol is a depressant and can alter your mood, thinking and behaviour.

Organ transplants and stem cells

- Organ transplants are where faulty and unhealthy body organs are replaced, usually with a healthy organ from another person.
- Stem cells are unspecialised cells that can reproduce themselves indefinitely and so could be used for organ transplant.
- The use of stem cells is regulated by the Australian Health Ethics Committee.

3.10.2 Key terms

absorption the taking in of a substance; for example, from the intestine to the surrounding capillaries
alcohol a colourless volatile flammable liquid (such as ethanol, C_2H_5OH) that is made by fermentation of sugars and starches
alveoli tiny air sacs in the lungs at the ends of the narrowest tubes. Oxygen moves from alveoli into the surrounding blood vessels, in exchange for carbon dioxide. Singular = alveolus
amphetamines nervous system stimulants, such as 'speed'
amylases enzymes in saliva that break down starch into sugar
antigens substance that stimulates the production of antibodies
anus the final part of the digestive system, through which faeces are passed as waste
aorta a large artery through which oxygenated blood is pumped at high pressure from the left ventricle of your heart to your body
arteries hollow tubes (vessels) with thick walls carrying blood pumped from the heart to other body parts
arterioles vessels that transport oxygenated blood from the arteries to the capillaries
ATP molecule used by cells in chemical reactions that require energy. ATP is a product of cellular respiration.
barbiturates chemicals that inhibit or decrease synaptic transmission and are hence depressants. They are often taken to calm people down and are used as sedatives.
bladder sac that stores urine
blastocyst a cluster of cells formed in early stages of mammal embryo development, containing an inner cell mass
bolus round, chewed-up ball of food made in the mouth that makes swallowing easier
bronchi the narrow tubes through which air passes from the trachea to the smaller bronchioles and alveoli in the respiratory system. Singular = bronchus.
bronchioles small branching tubes in the lungs leading from the two larger bronchi to the alveoli
caffeine an excitatory psychoactive drug that stimulates or increases synaptic transmission
capillaries minute tubes carrying blood to body cells. Every cell of the body is supplied with blood through capillaries.
carbon dioxide a colourless gas in which molecules (CO_2) are made up of one carbon and two oxygen atoms; essential for photosynthesis and a waste product of cellular respiration. The burning of fossil fuels also releases carbon dioxide.
cellular respiration a series of chemical reactions in which the chemical energy in molecules such as glucose is transferred into ATP molecules, which is a form of energy that the cells can use
chemical digestion the chemical reactions changing food into simpler substances that are absorbed into the bloodstream for use in other parts of the body
circulatory system the body system that includes the heart, blood and blood vessels and is responsible for circulating oxygen and nutrients to your body cells and carbon dioxide and other wastes away from them
cocaine an example of an excitatory psychoactive drug that stimulates or increases synaptic transmission
colon the part of the large intestine where a food mass passes from the small intestine, and where water and other remaining essential nutrients are absorbed into your body
constipation a condition of the bowels, caused by lack of dietary fibre, in which solid wastes cannot easily leave
dehydrated state in which too much water has been lost from the body
deoxygenated blood blood from which some oxygen has been removed
depressants inhibitory psychoactive drugs that reduce or decrease synaptic transmission
diabetes mellitus a medical condition in which the liver cannot effectively convert glucose to glycogen
digestion breakdown of food into a form that can be used by an organism. It includes both mechanical digestion and chemical digestion.

digestive system a complex system of organs and glands that processes food in order to supply your body with the nutrients to cells so they can function effectively
ecstasy an example of an excitatory psychoactive drug; a synthetic hallucinogenic drug (methylenedioxymethamphetamine, MDMA)
embryonic stem cells stem cells derived from the inner cell mass of a blastocyst. These cells are pluripotent and can give rise to most cell types.
endocrine system the body system composed of different glands that secrete signalling molecules (hormones) that travel in the blood for internal communication and regulation and to maintain homeostasis
endorphins hormones resembling opiates that are released by the brain when you are in pain, in danger or under other forms of stress
enzymes special chemicals that speed up reactions but are themselves not used up in the reaction
erythrocytes red blood cells
excitatory psychoactive drugs chemicals such as caffeine that increase or stimulate synaptic transmission
excretory system the body system that removes waste substances from the body
fats organic substances that are solid at room temperature and are made up of carbon, hydrogen and oxygen atoms
gall bladder a small organ that stores and concentrates bile within the body
GHB gamma hydroxybuturate, also known as liquid E or fantasy, which depresses the nervous system
glucagon a hormone, produced by the pancreas, that increases blood glucose levels
glucose a six-carbon sugar (monosaccharide) that acts as a primary energy supply for many organisms
glycaemic index (GI) a measure of how quickly a particular food raises the level of blood sugar over a two-hour period
glycogen the main storage carbohydrate in animals, converted from glucose by the liver and stored in the liver and muscle tissue
haemoglobin the red pigment in red blood cells that carries oxygen
heart a muscular organ that pumps blood through the circulatory system so that oxygen and nutrients can be transported to the body's cells and wastes can be transported away
heroin an inhibitory psychoactive drug that decreases synaptic transmission
inhibitory psychoactive drugs chemicals, such as barbiturates, that decrease synaptic transmission
insulin hormone that removes glucose from the blood and stores it as glycogen in the liver and muscles
kidneys body organs that filter the blood, removing urea and other wastes
large intestine the penultimate part of the digestive system, where water is absorbed from the waste before it is transported out of the body
left atrium upper left section of the heart where oxygenated blood from the lungs enters the heart
left ventricle lower left section of the heart, which pumps oxygenated blood to all parts of the body
lipases enzymes that break fats and oils down into fatty acids and glycerol
liver largest gland in the body. The liver secretes bile for digestion of fats, builds proteins from amino acids, breaks down many substances harmful to the body and has many other essential functions.
lungs the organ for breathing air. Gas exchange occurs in the lungs.
marijuana plant in which the active ingredient is an inhibitory psychoactive drug that reduces or decreases synaptic transmission; sometimes called cannabis
mechanical digestion digestion that uses physical factors such as chewing with the teeth
minerals any of the inorganic elements that are essential to the functioning of the human body and are obtained from foods
multipotent stem cells that can differentiate into only a few cell types
nephrons the filtration and excretory units of the kidney
nervous system he body system in which messages are sent as electrical impulses (along neurons) and chemical signals (neurotransmitters across synapses)
neurotoxic leads to the death of neurons
neurotransmitters signalling molecules released from the axon terminals into the synapse between nerve cells (neurons)
oesophagus part of the digestive system composed of a tube connecting the mouth and pharynx with the stomach
opiates drugs derived from the opium poppy that involve the neurotransmitter dopamine in stimulating pleasure centres in the brain; they may also induce sleep and alleviate pain
oxygen tasteless and colourless gas in which molecules (0_2) are made up of two oxygen atoms. It is essential for cellular respiration for most organisms and is a product of photosynthesis.

pancreas a large gland in the body that produces and secretes the hormone insulin and an important digestive fluid containing enzymes
peristalsis the process of pushing food along the oesophagus or small intestine by the action of muscles
pluripotent stem cells that can differentiate into most cell types; for example, blood cells, skin cells and liver cells
proteases enzymes that break proteins down into amino acids
psychoactive drugs chemicals that decrease synaptic transmission (such as barbiturates) or increase synaptic transmission (such as caffeine)
pulmonary artery the vessel through which deoxygenated blood, carrying wastes from respiration, travels from the heart to the lungs
pulmonary vein the vessel through which oxygenated blood travels from your lungs to the heart
receptors special cells that detect energy and convert it to electrical energy that is sent to the brain.
rectum the final section of the digestive system, where waste food matter is stored as faeces before being excreted through the anus
red blood cells living cells in the blood that transport oxygen to all other living cells in the body. Oxygen is carried by the red pigment haemoglobin.
respiratory system the body system that includes the lungs and associated structures and is responsible for the gas exchange of getting oxygen into your body and carbon dioxide out
right atrium upper right section of the heart where deoxygenated blood from the body enters
right ventricle lower right section of the heart, which pumps deoxygenated blood to the lungs
saliva watery substance in the mouth that moistens food before swallowing and contains enzymes involved in the digestion of food
salivary glands glands in the mouth that produce saliva
skin external covering of an animal body
small intestine the part of the digestive system between the stomach and large intestine, where much of the digestion of food and absorption of nutrients takes place
somatic stem cells undifferentiated multipotent cells that are found in adults and umbilical cord blood; they can generate only certain types of cells
stimulants excitatory psychoactive drugs, such as caffeine and amphetamines, that increase or stimulate synaptic transmission
stomach a large, hollow muscular organ that digests the bolus and secretes acids and enzymes for further digestion and temporary storage
THC the active ingredient in marijuana; also known as delta-9 tetrahydrocannobinol
totipotent the most powerful stem cells that can differentiate into all cell types
trachea narrow tube from the mouth to the lungs through which air moves
Type 1 diabetes mellitus a disease in which the pancreas stops producing insulin, so the body's cells cannot turn glucose into energy
Type 2 diabetes mellitus the most common form of diabetes, where the pancreas makes some insulin but does not produce enough
umbilical cord stem cells stem cells that can develop into a few types of cells (mainly blood cells and cells involved in fighting disease) and are also being used to treat leukaemia and other blood disorders
ureters tubes from each kidney that carry urine to the bladder
urine yellowish liquid, produced in the kidneys. It is mostly water and contains waste products from the blood such as urea, ammonia and uric acid.
veins blood vessels that carry blood back to the heart. They have valves and thinner walls than arteries.
vena cava large vein leading into the top right chamber of the heart
venules small veins
villi tiny finger-like projections from the wall of the intestine that maximise the surface area of the structure to increase the efficiency of nutrient absorption. Singular = villus
vitamin-deficiency diseases diseases caused by a lack of any vitamins in the diet
vitamins organic nutrients required in small amounts. They include vitamins A, B, C, D and K.

Resources

eWorkbooks	Study checklist (ewbk-4781) Literacy builder (ewbk-4782) Crossword (ewbk-4784) Word search (ewbk-4786)
Practical investigation eLogbook	Topic 3 Practical investigation eLogbook (elog-0546)
Digital document	Key terms glossary (doc-34917)

3.10 Exercise

learnon

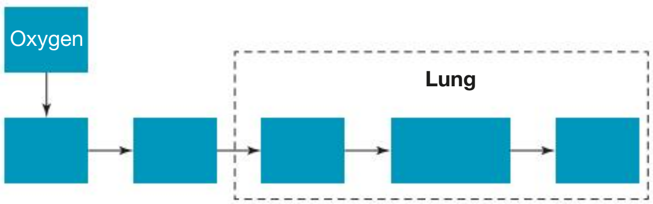
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

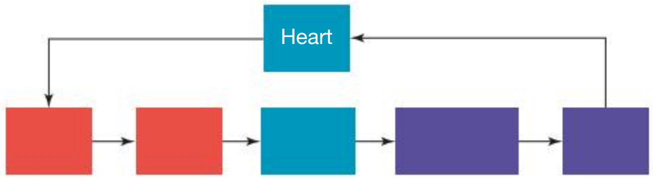
Select your pathway

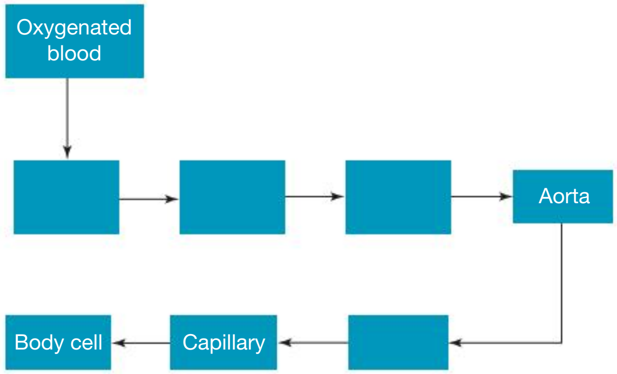
LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 5, 12	Questions 3, 6, 8, 10, 14	Questions 4, 7, 9, 11, 13

Remember and understand

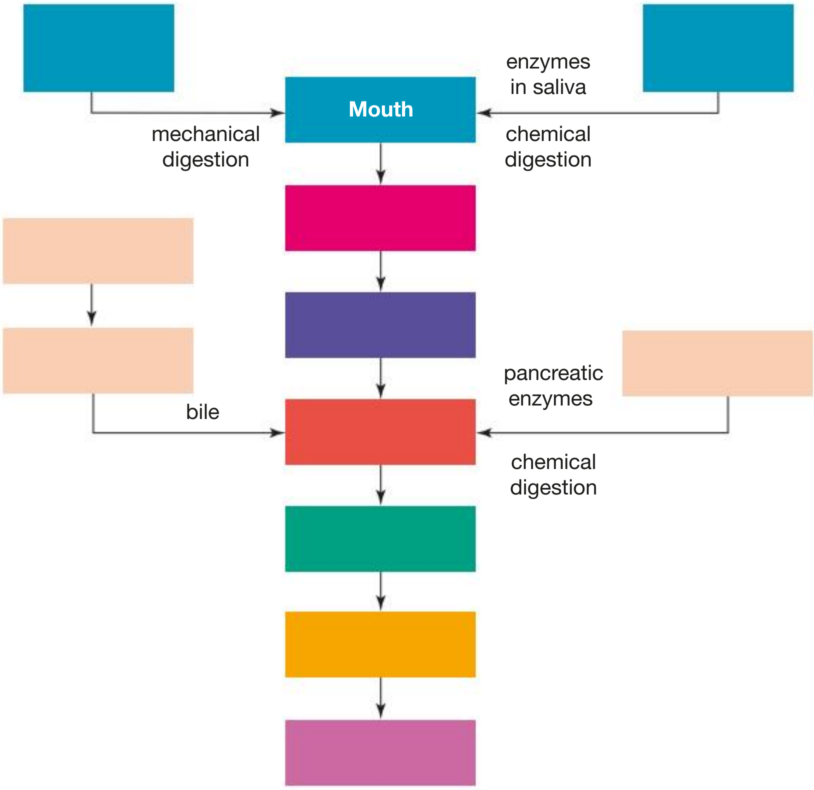
1. Identify whether the following statements are true or false. Justify any false response.
   a. Your circulatory and respiratory systems work together to provide your cells with carbon dioxide for cellular respiration.
   b. Arteries transport blood to the heart whereas veins transport blood away from it.
   c. Oxygen moves from the alveoli of your respiratory system into the red blood cells in the surrounding capillaries of your circulatory system.
   d. The left atrium of the heart contains oxygenated blood.
   e. Oxygenated blood travels from your lungs via the pulmonary vein to the right atrium of your heart.
2. Select the appropriate terms to complete the flow charts shown below: trachea, bronchi, arterioles, pulmonary vein, artery, left atrium, capillary, alveoli, body cells, left ventricle, capillary, vein, nose, bronchioles.

a.


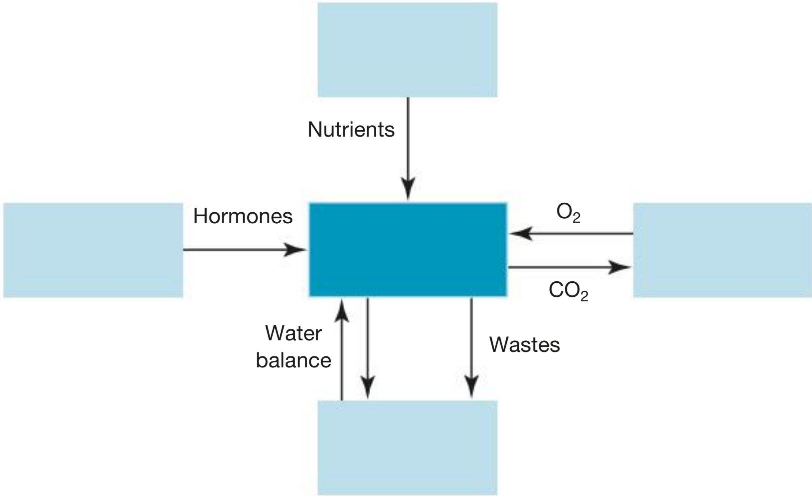
b.


c. 

3. Select the appropriate terms to complete the flow chart.
oesophagus, teeth, salivary glands, stomach, large intestine, mouth, anus, small intestine, rectum, liver, gall bladder



4. Suggest which body systems belong in each of the blank boxes in the figure.



5. Match the organ with the unwanted product or waste that it excretes.

Organ	Unwanted product or waste to be excreted
a. Kidney	A. Bile pigments from old red blood cells
b. Liver and large intestine	B. Carbon dioxide
c. Lungs	C. Urea

6. Complete the sentences to describe each body system.

Term	Function
a. Respiratory system	To get ___________________ into your body and ___________________ out
b. Circulatory system	To transport ___________________ and ___________________ to your body cells, and wastes such as ___________________ away from them
c. Digestive system	To supply your body with ___________________ such as ___________________ so that it functions effectively
d. Excretory system	To remove ___________________ products of a variety of necessary chemical reactions
e. Endocrine system	Uses chemical messengers called ___________________ secreted from special glands called ___________________ throughout the body to control and coordinate at both cellular and system level
f. Nervous system	Uses ___________________ and chemical messengers called ___________________ to control and coordinate at both cellular and system level

7. Complete the table.

TABLE Types of nutrients

Nutrient	Why it is needed?	Examples of sources
a. Carbohydrate		
b. Protein		
c. Lipid		
d. Vitamin		
e. Mineral		

Apply and analyse

8. Which am I? Match the chemical in the list that follows to the most appropriate description below:

Term	Function
a. potassium	A. I am needed by red blood cells to carry oxygen to tissues.
b. vitamin A	B. I assist nerves in functioning and a deficiency may cause fatigue and slow reflexes.
c. fat	C. I am made up of amino acids and can make up hormones and enzymes.
d. iron	D. I can be stored under the skin and am solid at room temperature.
e. protein	E. I am a polysaccharide that is not digested but can increase the fibre in your diet.
f. cellulose	F. I am a fat-soluble vitamin that is needed for healthy lining of your digestive and respiratory systems.
g. starch	G. I am a polysaccharide that can be digested and broken down into glucose.

9. Explain how the shapes of the following structures suit them to their function.
   a. Trachea
   b. Oesophagus
   c. Nephrons
   d. Villi
   e. Alveoli

Evaluate and create

10. Describe the relationship between the respiratory, circulatory, excretory and digestive systems and cellular respiration.
11. Is it the level of oxygen or carbon dioxide in your blood that has the major influence on breathing rate? How are variations in blood concentrations detected?
12. What is foetal alcohol syndrome? Find out about some other effects of alcohol on the developing foetus.
13. Find out how an alcohol breathalyser works.

14. In the media, many foods are called ‘superfoods’. The table provides some examples of these and the suggested beneficial implications of chemicals that they contain.
    a. Research the active chemical in each of these ‘superfoods’.
    b. Compare the level of these chemicals in the foods listed with the other examples of foods with high levels of the same chemical.
    c. Decide whether you think each of these foods deserves being labelled a superfood. Justify your decisions.

TABLE Foods classified as ’superfoods’ based on the presence of active chemicals

Food		Super’ property	Active chemical	Examples of other foods with high levels of this chemical
Watermelon		Sun protection	Lycopene	Red capsicums, tomatoes, green tea
Coriander		Anti-ageing	Beta-carotene and vitamin C	Berries, broccoli, carrots
Onions		Cancer fighting	Quercetin	Apples, oranges, parsley
Mussels		Metabolism	Selenium	Tuna, eggs, Brazil nuts
Black pepper		Antidepressant	Piperine	Salmon, dark chocolate, bananas

Fully worked solutions and sample responses are available in your digital formats.

on Resources

eWorkbook Reflection (ewbk-3038)

teachon

Test maker
Create customised assessments from our extensive range of questions, including teacher-quarantined questions. Access the assignments section in learnON to begin creating and assigning assessments to students.

RESOURCE SUMMARY

on Resources

Below is a full list of **rich resources** available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

3.1 Overview

eWorkbooks
- Topic 3 eWorkbook (ewbk-4759)
- Student learning matrix (ewbk-4758)
- Starter activity (ewbk-4761)

Practical investigation eLogbook
- Topic 3 Practical investigation eLogbook (elog-0546)

Video eLesson
- Body systems animation (eles-4171)

3.2 Respiratory and circulatory systems

eWorkbooks
- Labelling the human respiratory system (ewbk-4763)
- Labelling the heart (ewbk-4765)

Video eLessons
- Organs of the respiratory system (eles-2642)
- Blood flows through the heart (eles-2049)

Interactivites
- Beat it! (int-0210)
- Labelling the human respiratory system (int-8233)

3.3 Essential intake

Practical investigation eLogbook
- Investigation 3.1: Essential testing (elog-0548)

3.4 Digestive and excretory systems

eWorkbooks
- Labelling the human digestive system (ewbk-4767)
- The digestive system (ewbk-4769)
- Labelling the kidneys (ewbk-4771)
- Removing waste from blood (ewbk-4773)

Video eLessons
- The human digestive system (eles-2643)
- Urine formation in the kidney (eles-2644)

Interactivites
- The digestive system (int-3398)
- Labelling the kidneys (int-8234)

3.5 Living warehouses

Practical investigation eLogbooks
- Investigation 3.2: Measuring the energy in food (elog-0550)
- Investigation 3.3: Energy for living (elog-0552)

3.10 Review

eWorkbooks
- Topic review Level 1 (ewbk-4775)
- Topic review Level 2 (ewbk-4777)
- Topic review Level 3 (ewbk-4779)
- Study checklist (ewbk-4781)
- Literacy builder (ewbk-4782)
- Crossword (ewbk-4784)
- Word search (ewbk-4786)
- Reflection (ewbk-3038)

Practical investigation eLogbook
- Topic 3 Practical investigation eLogbook (elog-0546)

Digital document
- Key terms glossary (doc-34917)

To access these online resources, log on to **www.jacplus.com.au**.

4 The body at war

LEARNING SEQUENCE

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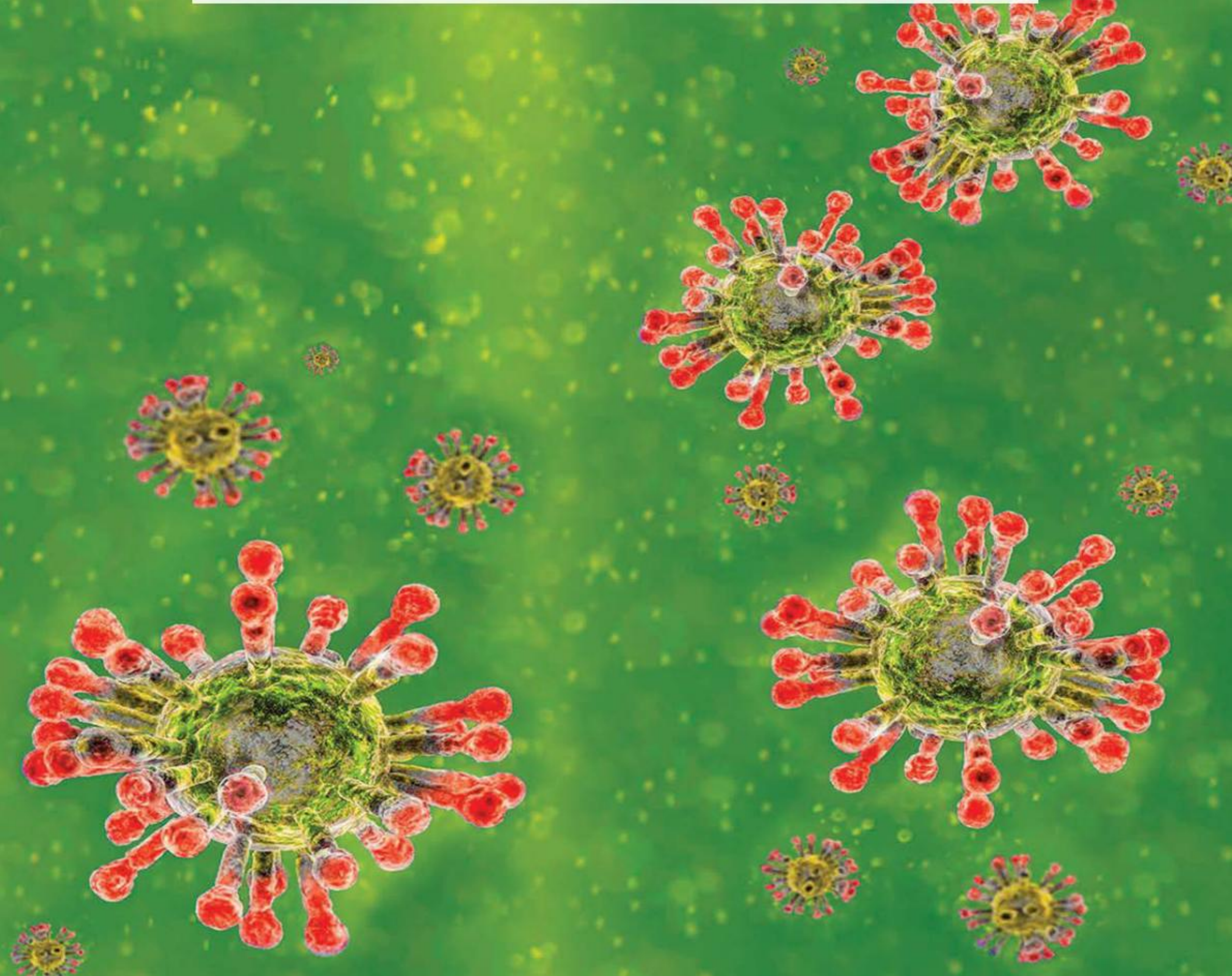


4.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

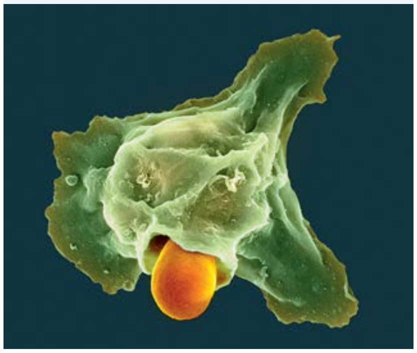
4.1.1 Introduction

Lines of defence, soldier cells and chemical weapons all form a part of the amazing array of strategies used by our bodies to keep us healthy.

Figure 4.1 shows a coloured scanning electron micrograph of a lymphocyte (white blood cell, shown in green) engulfing a yeast cell (shown as orange). The lymphocyte is using projections of its cytoplasm to extend towards the yeast spore, which will be swallowed up and digested.

In this topic we will explore how infectious diseases have shaped the world and the medical breakthroughs that have been developed in response to these challenges. At the heart of these medical breakthroughs is the improved understanding of how our bodies respond to disease.

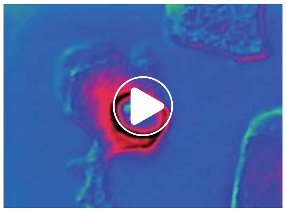
FIGURE 4.1 Your body has many ways to defend itself, including using 'soldier cells' such as this neutrophil white blood cell.



on Resources

Video eLesson The body at war (eles-4188)

Watch this light microscopy time-lapse footage of a white blood cell (entering from lower right) sensing, moving towards, and ingesting a yeast cell (centre). The white blood cell is a neutrophil, which are involved in defence against infections, in this case by a yeast fungus. Indicator dye has been added to demonstrate that the white blood cell is using its lethal oxidative ability to kill the yeast.



4.1.2 Think about the body at war

1. What is an infectious disease?
2. What are the differences between viruses and bacteria?
3. What is a parasite?
4. What is the Black Death and how does it spread?
5. Is immunisation necessary?
6. What animal up to 10 metres long can live inside a living human body?
7. What does H5N1 have to do with birds?
8. How did COVID-19 become a global pandemic?
9. Is diabetes contagious?
10. Why are anthrax, cholera, botulism and smallpox attractive to terrorists?

4.1.3 Science inquiry

Using stories and rituals to pass on knowledge about food safety

Throughout history, stories and rituals have been used to pass knowledge about food and nutrition from one generation to the next.

Goldilocks and the Three Bears

1. Imagine that Goldilocks got sick after eating the porridge. Suggest some reasons why this may have happened.

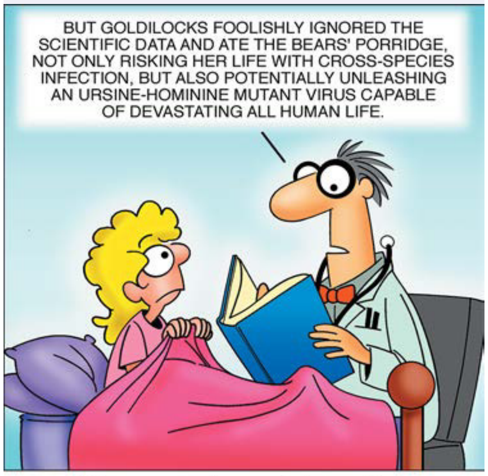
2. The Three Bears did not cover their porridge while they went for their walk. Was this a good idea or not? Give reasons for your answer.
3. How long can porridge stay uncovered at room temperature before it is dangerous to eat? Find out the spoiling time of four other foods.
4. Create your own fairytale to teach young children about poisonous or spoiled food. Present your story as a PowerPoint presentation, storybook, pantomime or puppet play.

Tutankhamen

Baskets of food, along with jars of wine and oil, were found in Tutankhamen's tomb in Egypt in 1922 (see figure 4.3). Other Egyptian tombs contained honey that was in a well-preserved state; when opened it retained some of its aroma. Today, most foods have a use-by or best-before date on the packaging.

5. For three different foods, find out what might happen, and why, if you used it well after its use-by date.
6. Sometimes canned food is unsafe to eat. Find out why.
7. Find out what strategies humans have to survive eating lots of different foods, some of which may cause food poisoning.

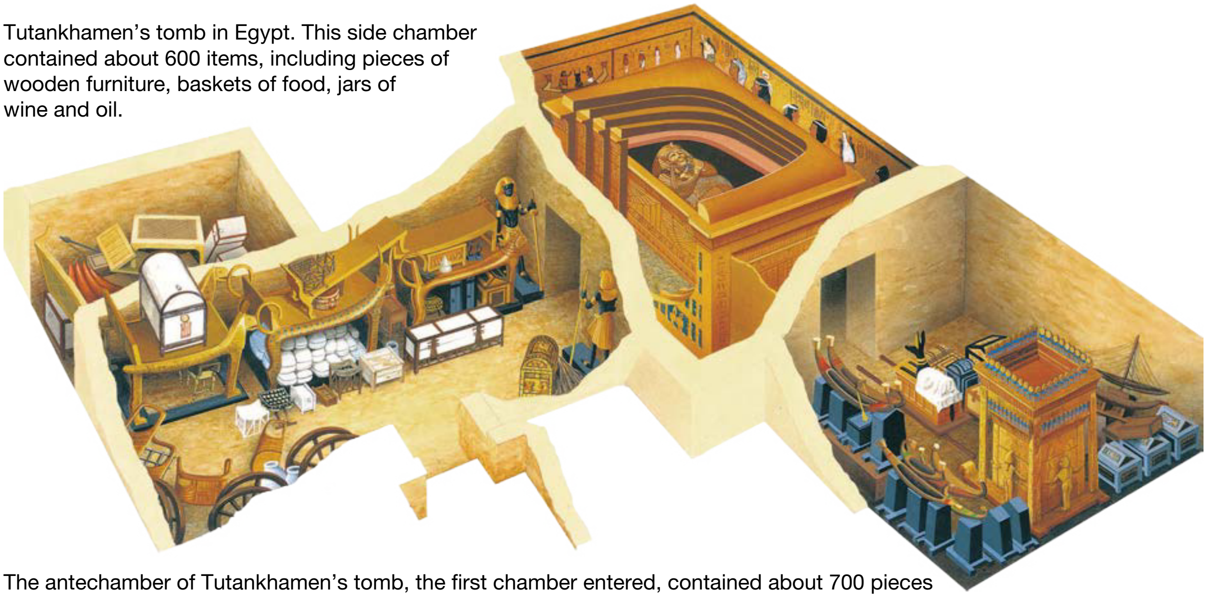
FIGURE 4.2 Why might it have been dangerous for Goldilocks to eat the bears' porridge?



A Very Grimm Fairytale

FIGURE 4.3 Inside the tomb of Tutankhamen

Tutankhamen's tomb in Egypt. This side chamber contained about 600 items, including pieces of wooden furniture, baskets of food, jars of wine and oil.



The antechamber of Tutankhamen's tomb, the first chamber entered, contained about 700 pieces of furniture, a chariot (in bits) and two black and gold life-size statues either side of the entrance. There were also jars of oil, lamps, vases, musical instruments, board games and clothing.

on Resources

eWorkbooks	Topic 4 eWorkbook (ewbk-5182) Student learning matrix (ewbk-5184) Starter activity (ewbk-5185)
Practical investigation eLogbook	Topic 4 Practical investigation eLogbook (elog-0669)
learnon	Access and answer an online Pre-test and receive **immediate corrective feedback** and **fully worked solutions** for all questions

4.2 Catch us if you can

LEARNING INTENTION

At the end of this subtopic you will be able to understand what infectious diseases are, how they are spread and the range of strategies that can prevent or contain the spread of them.

4.2.1 Classifying diseases

Something wrong? Not feeling well? You may have a disease! A human **disease** can be defined as being any change that impairs the function of an individual in some way; it causes harm to the individual. Diseases can be classified as being infectious or non-infectious.

FIGURE 4.4 Diseases can be infectious, or non-infectious.

Non-infectious diseases — can't catch us!

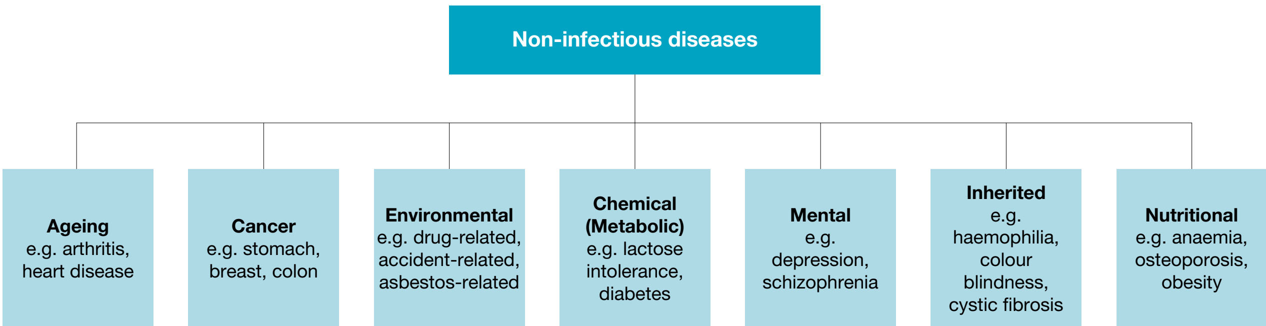
Non-infectious diseases cannot be spread from one person to another; they are not contagious (transferred from one organism to another). Obesity, rickets and scurvy are examples of non-infectious diseases that may be related to unbalanced diets or nutritional deficiencies. Inherited diseases such as haemophilia and cystic fibrosis and diseases related to exposure to particular poisons or drugs are also non-infectious. Although **viruses** have been implicated in some cancers (for example, cancer of the cervix), most cancers are considered to be non-infectious diseases.

disease any change that impairs the function of an organism in some way and causes it harm

non-infectious disease a disease that cannot be spread from one organism to another

virus a very simple microorganism that infects cells and may cause disease

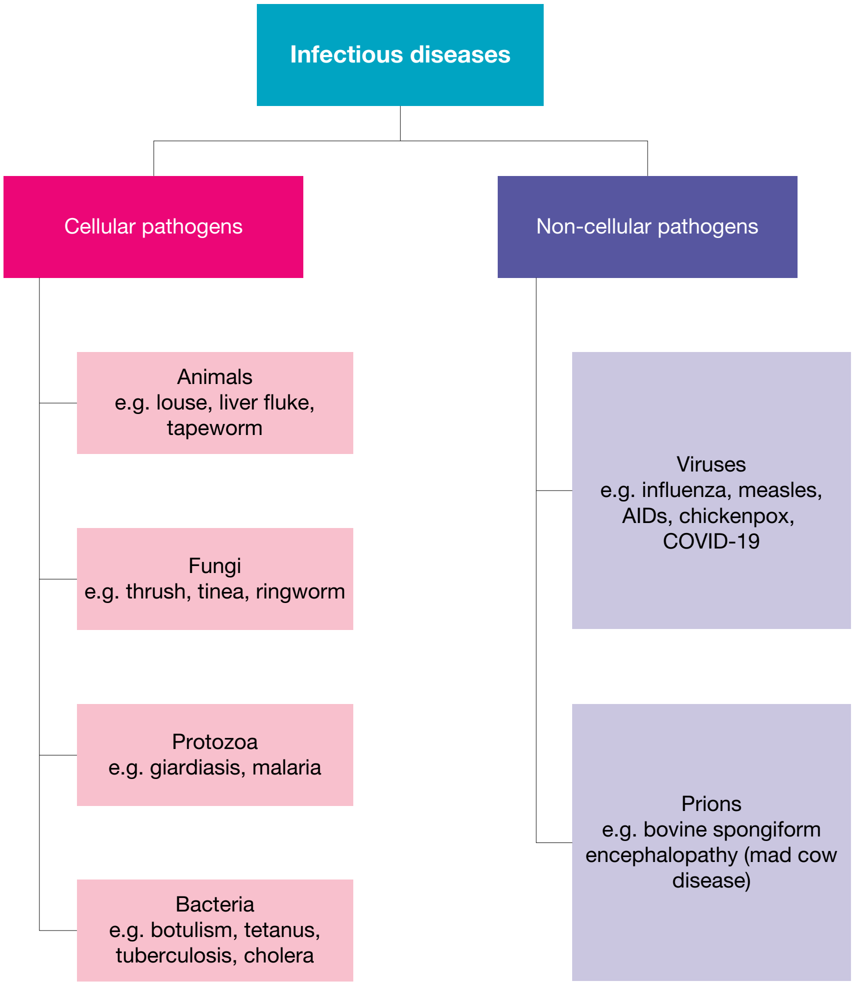
FIGURE 4.5 Non-infectious diseases include diabetes, heart disease and cancer.



Infectious diseases — can catch us!

Infectious diseases are diseases that are contagious and are caused by a **pathogen**. Tapeworms, head lice, liver flukes, fungi, protozoans and bacteria are examples of pathogens that are made up of cells and can be referred to as **cellular pathogens**. Some other pathogens, such as viruses, are not made up of cells and for this reason are sometimes referred to as **non-cellular pathogens**.

FIGURE 4.6 Infectious diseases in humans



infectious disease a disease that is contagious (can be spread from one organism to another) and caused by a pathogen

pathogen a disease-producing organism

cellular pathogen a pathogen that is made up of cells, such as a tapeworm, fungus or bacterium

non-cellular pathogen a pathogen that is not made up of cells, such as a virus, prion or viroid

quarantine strict isolation of sick people from others for a period of time (originally 40 days) in order to prevent the spread of disease

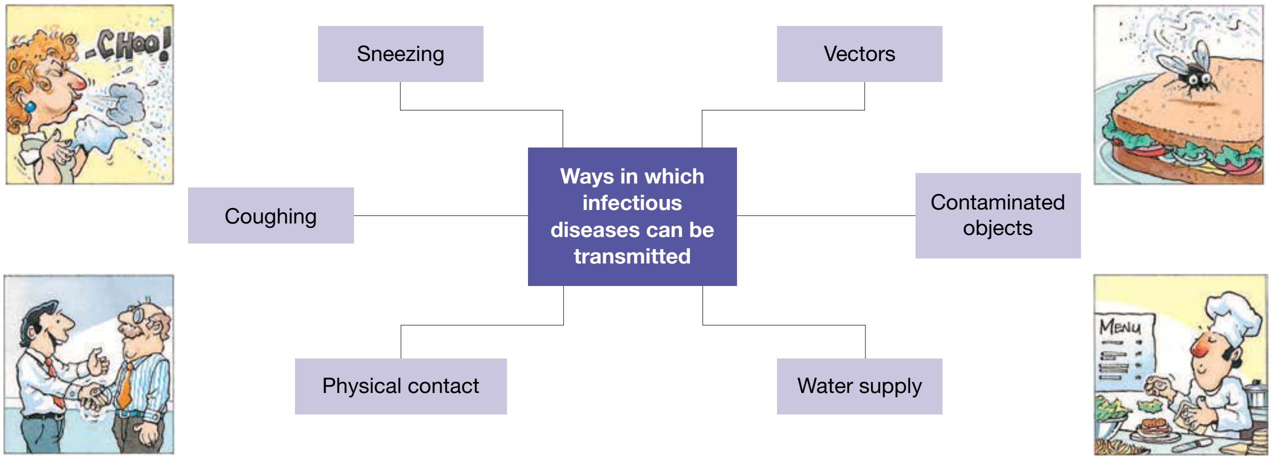
4.2.2 The spread of infectious diseases

Preventing the spread of infectious diseases has been a challenge throughout history. The ancient Hebrews isolated those with disease by keeping them away from others or by sending them beyond the boundaries of the towns. In the Middle Ages, Mediterranean people refused to allow ships to dock for forty days if they carried sick people. The separation of sick people from healthy people to avoid infection was the beginning of **quarantine**. Unfortunately these methods were not enough to stop large outbreaks of disease.

WHAT DOES IT MEAN?

The word quarantine is derived from the Latin word ***quadrāgintā***, meaning 'forty'. In the Middle ages, sick people were strictly isolated for a period of 40 days in order to prevent the spread of disease.

FIGURE 4.7 Different ways in which infectious diseases can be transmitted



The knowledge of how infectious diseases are transmitted is important if ways to control their spread are to be found. Some key ways in which pathogens may be transmitted include direct contact, vectors, contaminated objects or contaminated water supplies.

Direct contact

Some diseases are spread by direct contact. Touching others or being touched is one way in which pathogens can be directly transferred from one person to another.

Another way is via airborne droplets that are produced when you cough, sneeze or talk. These droplets may contain pathogenic bacteria or viruses and may land on objects or people around you, which may result in disease.

on Resources

Video eLesson Airborne droplets (eles-2645)

Interactivity Classifying diseases (int-5768)

Vectors

Some diseases are spread by vectors. **Vectors** are organisms that carry the disease-causing pathogen between organisms — without being affected by the disease themselves. Mosquitoes, houseflies, rats and mice are examples of organisms that can act as vectors to spread disease.

FIGURE 4.8 Mosquitoes are the vectors for many infectious diseases.

Contaminated objects

While fungal diseases such as tinea and ringworm can be spread by direct physical contact, they may also be transmitted by towels or surfaces that have been contaminated with skin cells of an infected person.

Food poisoning is often caused by contamination of food (or food utensils) with particular types of pathogenic bacteria called Salmonella. This can cause diarrhoea and vomiting, usually within 2–24 hours after injection. This is why washing your hands is so important after going to the toilet and before touching food or being involved in food preparation.

vector an organism that carries a pathogen between other organisms without being affected by the disease the pathogen causes

Contaminated water

Many pathogenic organisms live in water and are carried about in it. Our domestic water supplies are usually chemically treated to kill disease-causing micro-organisms within it. However, this may not be the case with water drunk directly from water tanks, rivers or creeks. This water may need to be boiled before it is drunk.

During the summer months, the Environment Protection Authority (EPA) measures the levels of *Escherichia coli* (*E. coli*) bacteria in water in coastal beaches. The level of *E. coli* in the water is used as an indicator of levels of potentially pathogenic bacteria, as it is found in faeces.

4.2.3 Fighting the spread

There are a number of ways in which the spread of disease may be controlled. These include personal hygiene, care with food preparation, proper disposal of sewage and garbage, chemical control of vectors, chemical treatment of clothes, surfaces and water, pasteurisation of milk, public education programs, quarantine laws and the use of drugs such as antibiotics.

on Resources

eWorkbooks Infectious diseases (ewbk-5187)
Non-infectious diseases (ewbk-5189)

assesson Additional automatically marked question sets

4.2 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

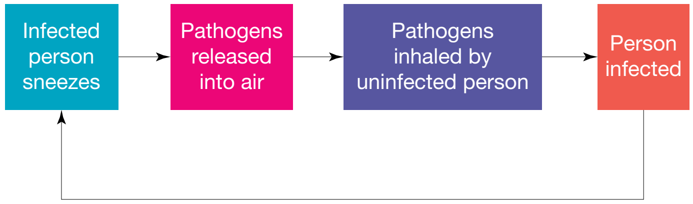
1. Define the following terms and give one example for each of them.
   a. disease
   b. non-infectious disease
   c. infectious disease
   d. pathogen
   e. contagious
   f. vector.
2. Identify three differences between non-infectious diseases and infectious diseases.
3. Bacteria causes tuberculosis, a virus causes Ebola and malaria is caused by a parasite. Explain why all three are considered infectious diseases. What do these infectious agents have in common in their structures and functions?
4. Match the type of pathogen with the infectious disease.

Type of pathogen	Infectious disease
a. Animal	A. Giardiasis
b. Bacteria	B. Tinea
c. Fungi	C. Louse
d. Protozoans	D. Cholera
e. Viruses	E. Influenza

Apply and analyse

5. a. Media campaigns can be effective in improving our health by changing social behaviours. Explain how the social media campaign involving the DAB, which gained popularity as a dance move, impacted coughing etiquette and the spread of the common cold and influenza.
   b. List another five ways of preventing the spread of colds and flu.
6. The flow chart provided describes how disease can be spread by sneezing. Construct similar flow charts to show three different ways in which diseases can be spread.

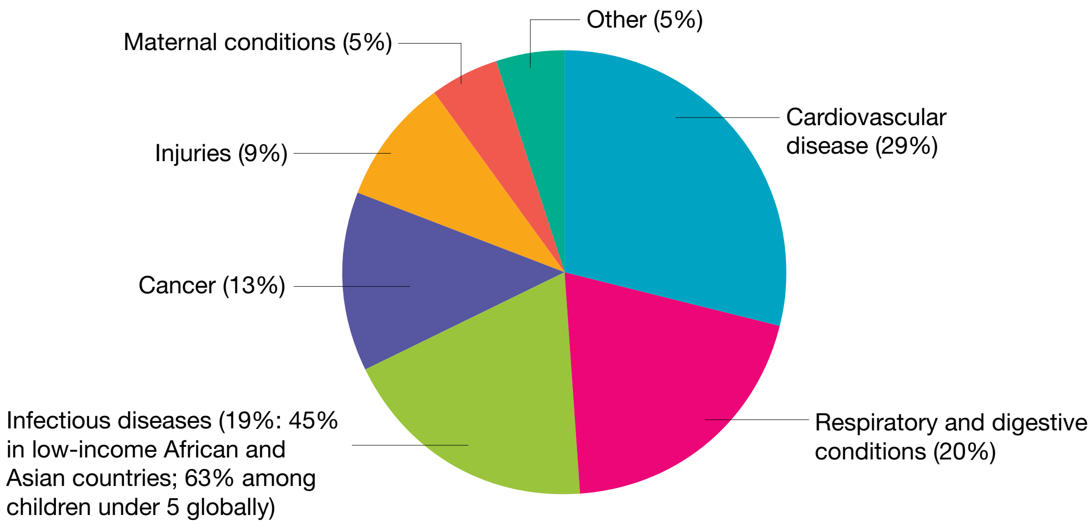
Some infectious diseases can be spread from one person to another via a sneeze.



Evaluate and create

7. **SIS** Study the pie chart provided. It shows the main causes of death worldwide in 2002.
   a. State the percentage of people who died from infectious diseases:
      i. worldwide
      ii. in low-income African and Asian countries.
   b. Suggest why there is such a large difference in the percentage of people who died from infectious disease between wealthier countries and poor countries.
   c. State the percentage of children who died before the age of five of infectious diseases. Suggest why this figure is so high. (*Hint*: Think about the other main causes of death and who they are likely to affect.)
   d. Draw a column graph to represent the data shown in the pie chart.
   e. If the same data was collected in 2020 and a similar graph was drawn, how do you think the two graphs would differ? Give reasons for your answer.

Main causes of death worldwide in 2002



8. Which pathogen is the most common cause of food poisoning due to consumption of undercooked chicken? What symptoms are observed? How many hours after consumption does it take for the onset of symptoms?
9. **SIS** Predict social or ethical issues that might arise in designing policies for disease prevention.

Fully worked solutions and sample responses are available in your digital formats.

4.3 The good, the bad and the ugly

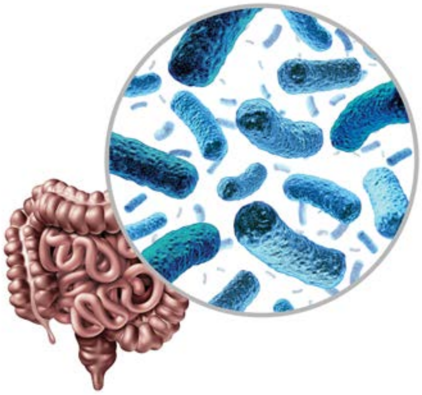
LEARNING INTENTION

At the end of this subtopic you will be aware that not all microorganisms cause disease, be able to provide examples of some different types of pathogens that exist and be able to describe how pathogens can cause diseases in a host.

4.3.1 The good guys — our microbiome

We do not live alone! There are trillions of microorganisms that live on us and in us, our **microbiome**. There are more of them than our own cells. We need them and they need us to survive. They even play a role in defending us from attack from outside invaders. Our microbiome is continually changing and no two people have the same microbiome. Development of our microbiome begins at birth, with the bacteria that colonises our intestines, and these are considered the normal **gut flora**. This gut flora varies depending upon whether the birth was a normal vaginal birth or a caesarian section, and is continued to be influenced by whether the baby is breast or bottle fed. We depend on our gut bacteria to obtain vitamins K and B.

FIGURE 4.9 Gut probiotic bacterium inside small intestine and digestive microflora inside the bowel



Other factors that change our gut flora include:

- antibiotics — using antibiotics destroys both pathogical and beneficial microbes, which can promote the growth of other pathogens
- the environment in which we live (rural, city, developing countries)
- diet — vegetarian diets are associated with healthy diverse gut microbiota. Diets high in sugar can slow the production of proteins, which inhibits the growth of beneficial gut microbes. Many people now choose to boost their gut flora by consuming probiotics, which are living organisms. Prebiotics can also be beneficial. These promote the activity or structure of the current gut microbiota.

Bacteria do not live only in our gut, but all over our bodies. The skin under your armpits contains over two million bacteria per square centimetre. The unpleasant smell is caused not by the bacteria themselves, but is the result of the bacteria breaking down the proteins in your sweat. The bacteria in your armpits can prevent pathogenic bacteria from colonising, and so keeps you healthy.

4.3.2 Parasites

Some relationships between organisms may provide one with resources and can cause harm to the other. An example of this relationship is that involving a **parasite** and its host.

The organism that a parasite lives in or on is referred to as its **host**. The life cycle of parasites can involve one or more hosts. The **primary host** is the organism used for the adult stage and the **intermediate host** (or secondary host) is used for the larval stage.

microbiome the community of microorganisms (such as bacteria, fungi, and viruses) living together in a particular habitat

gut flora bacteria and other organisms that live inside the intestines and help digest food

parasite organism that obtains resources from another organism (host) that it lives in or on, and can cause harm to

host organism living in a relationship with another organism

primary host the organism that a parasite lives in or on in its adult stage

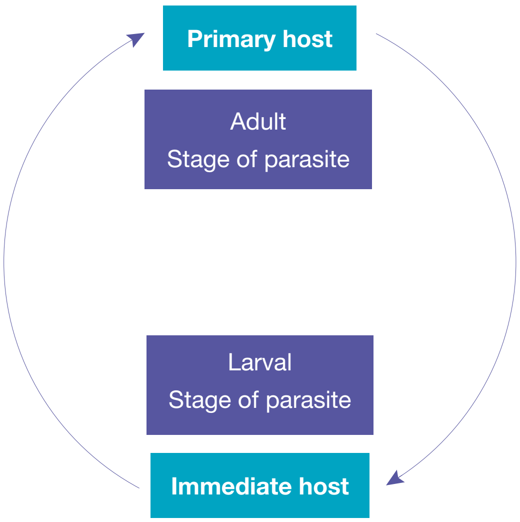
intermediate host the organism that a parasite lives in or on in its larval stage; also known as secondary host

Parasites can be classified on the basis of the part of your body in which they live.

- **Endoparasites**: parasites that live inside your body.
- **Ectoparasites**: parasites that live outside your body.

Some parasites can harm their hosts and cause disease; these parasites are also considered to be pathogens. However, not all parasites kill their hosts. It's probably a very good idea if they don't, because they rely on their host for resources. Both animals and plants carry parasites; for example, aphids are a parasite that feeds off rose bushes (figure 4.11).

FIGURE 4.10 The organism in which the parasite completes some part of its life cycle is referred to as its host.



4.3.3 Pathogens

Infectious diseases are caused by pathogens. Pathogens may be cellular (made up of cells) or non-cellular.

- Cellular pathogens include disease-causing bacteria, protists, fungi and animal.
- Non-cellular pathogens include: prions, viruses and **viroids**.

Pathogens cause harm to their hosts (the organism that they infect).

Non-cellular pathogens: Prions

Prions are non-cellular pathogens. The word *prion* is derived from the terms protein and infection. They are abnormal and infectious proteins that can convert your normal protein into prion protein. When cells containing prions burst, more of these infectious proteins are released to infect other cells. The bursting of these cells can also result in damage to the tissues of which they are a part.

Prions are thought to be responsible for degenerative neurological diseases. These diseases are also called **transmissible spongiform encephalopathies (TSE)**. The term spongiform is included because of the tiny holes that result from the bursting of infected cells, giving the brain a spongy appearance. Examples of these diseases include kuru, Creutzfeldt-Jakob disease (CJD) and bovine spongiform encephalopathy (BSE).

FIGURE 4.11 Rose aphids infesting a rose stem

BSE is commonly known as 'mad cow disease' because of the nervous or aggressive behaviour observed in infected cows. Hundreds of thousands of cattle were destroyed when it was discovered that humans could become infected with this disease by eating meat from infected cows.

endoparasite parasite that lives inside the body of its host organism

ectoparasite parasite that lives outside the body of its host organism

viroid non-cellular pathogen comprised solely of a short circular RNA without a protein coat

prion an abnormal and infectious protein that converts normal proteins into prion proteins

transmissible spongiform encephalopathy (TSE) a degenerative neurological disease caused by prions

DNA (deoxyribonucleic acid) a substance found in all living things that contains genetic information

RNA (ribonucleic acid) complex compound that functions in cellular protein synthesis and replaces DNA as a carrier of genetic codes

obligate intracellular parasite a parasite that needs to infect a host cell before it can reproduce

Non-cellular pathogens: Viruses

Viruses are another example of non-cellular pathogens. They consist of **DNA** or **RNA** enclosed within one or more protein coats. Viruses are so small that they can only be seen with very powerful electron microscopes.

Scientists debate whether viruses should be called living things, as they are **obligate intracellular parasites**. This means that they need to infect a host cell before they can reproduce; they cannot do it on their own. As viruses cause damage to their host cell in the process, they are also classified as being pathogens. Examples of infectious diseases caused by viruses include warts, rubella, mumps, poliomyelitis, influenza, AIDS, SARS-CoV-2 (the virus which causes COVID-19) and the common cold.

FIGURE 4.12 Viruses come in many shapes and sizes.

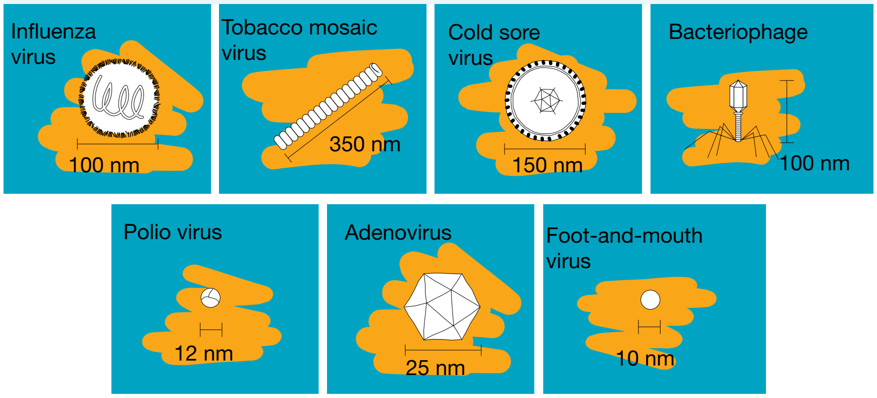


FIGURE 4.13 The influenza virus consists of RNA surrounded by protein and lipid layers. It is not cellular.

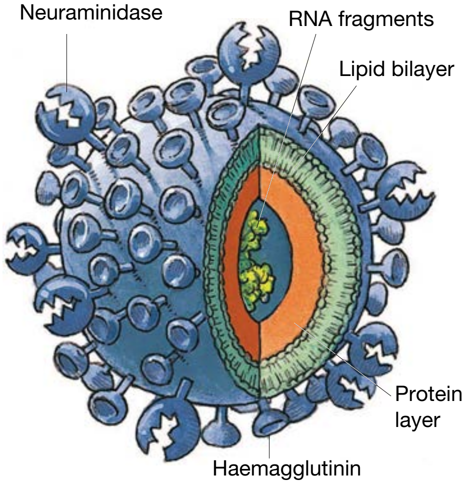
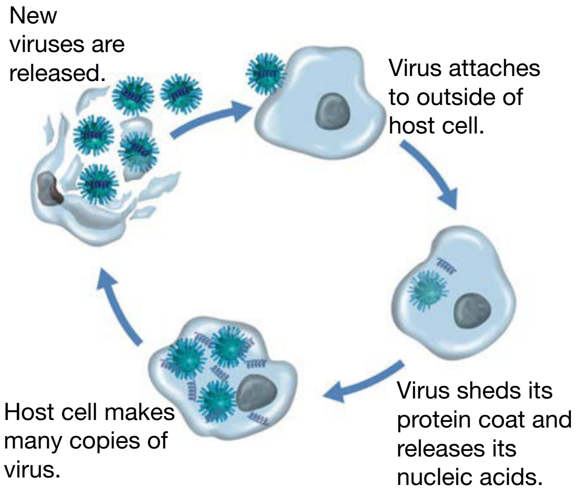


FIGURE 4.14 This cycle depicts how a virus is spread.



Cellular pathogens: Bacteria

Disease-causing bacteria are cellular pathogens that consist of a single cell. They can be classified on the basis of their cell shape, the organisation of colonies of bacteria and the presence or absence of structures (such as a flagellum) or particular chemicals in their cell wall.

A spherical bacterium is referred to as **coccus** (for example, *Staphylococcus*), a rod-shaped bacterium as **bacillus** (for example, *Bacillus*) and a spiral-shaped bacterium as **spirochaete**. Their colonies can be described as being single, in pairs, in chains or clustered together (figure 4.15).

coccus a spherical bacterium
bacillus a rod-shaped bacterium
spirochaete a spiral-shaped bacterium

Examples of diseases caused by bacteria include strep (short for *Streptococcus* — figure 4.16) throat, tetanus, pneumonia, food poisoning, gastroenteritis, cholera, gonorrhoea, leprosy, tetanus, scarlet fever, whooping cough, meningitis, typhoid and even pimples!

FIGURE 4.15 Some types of disease-causing bacteria

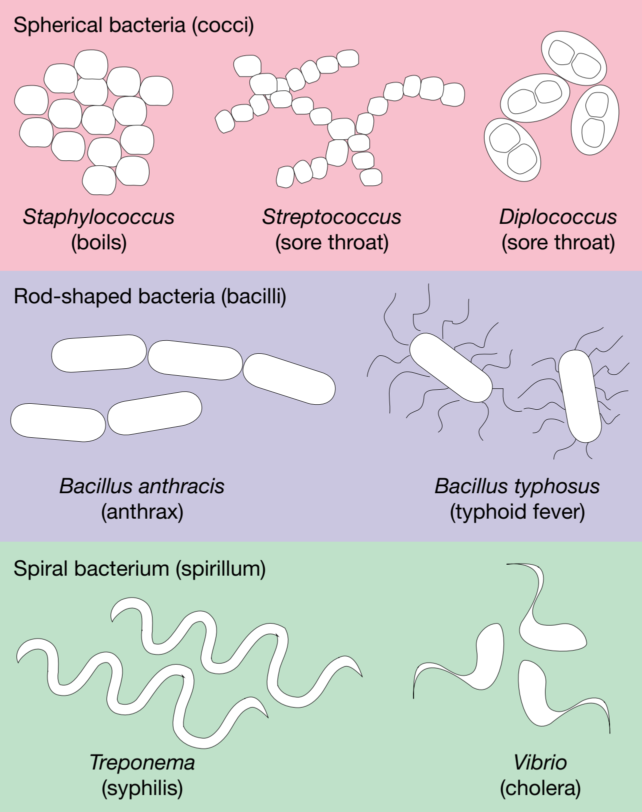
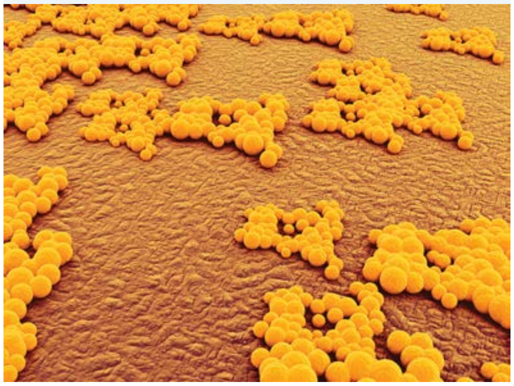


FIGURE 4.16 *Streptococcus bacteria*



CASE STUDY: Leprosy

Leprosy is rare in Australia, where it is known as Hansen's disease. It is caused by *Mycobacterium leprae*, a rod-shaped bacterium, and is a contagious disease that affects the skin, mucous membranes, and nerves, causing discolouration and lumps on the skin and, in severe cases, disfigurement and deformities. Leprosy is now mainly confined to tropical Africa and Asia. This disease is transmitted through droplets expelled by sneezes and coughs or by coming in contact with nasal fluids on surfaces.

Leprosy is curable with multidrug therapy, which involves treatment with two or more different antibiotics over a period of around 6 months. In the past 20 years, 16 million people worldwide have been cured of leprosy.

FIGURE 4.17 Leprosy may cause disfigurement or deformities in severe cases.

SCIENCE AS A HUMAN ENDEAVOUR: Pasteurisation

Did you know that it is illegal for raw cow's milk to be sold in Australia for human consumption? This is because raw milk can contain dangerously high levels of bacteria such as *Brucella, Campylobacter, Cryptosporidium, E. coli*, *Listeria*, and *Salmonella*, which can pose serious health risks.

Pasteurisation was first developed by Louis Pasteur in 1864. It kills harmful microorganisms responsible for such diseases as listeriosis, typhoid fever, tuberculosis, diphtheria, Q fever, and brucellosis. Pasteurisation makes sure that milk is safe to drink (by killing any bacteria) and also helps to prolong its shelf life. The process of pasteurisation involves heating milk to 71.7 °C for at least 15 seconds, and no more than 25 seconds. Once the milk has been heated, it is then cooled very quickly to less than 3 °C. Unlike sterilisation, pasteurisation does not kill *all* microorganisms and their spores.

Cellular pathogens: Protozoans

A number of infectious diseases are caused by parasitic protozoans. These single-celled organisms are usually found within their host's body. It is a good idea to know more about these diseases if you intend to go to tropical regions, where such diseases are more common. Examples of diseases caused by protozoans include head lice, malaria (see case study below), amoebic dysentery and African sleeping sickness.

Cellular pathogens: Fungi

Fungi belong to one of the biggest groups of organisms. They include some that are large, such as toadstools, and others that are microscopic, such as the **moulds** that grow on bread. Many fungi are parasites, feeding on living plants and animals, including humans. This often results in disease.

Common human diseases caused by fungi are tinea or athlete's foot, thrush and ringworm. Some fungi live in the mouth, the vagina and the digestive system at all times, without causing harm. However, if resistance to disease is low, the fungi in these places can become active and cause problems such as thrush.

fungi organisms, such as mushrooms and moulds — some help to decompose dead or decaying matter and some cause disease

moulds types of microscopic fungi found growing on the surface of foods

Cellular pathogens: Worms and arthropods

Larger parasites include endoparasites such as tapeworms, roundworms and liver flukes, and ectoparasites such as ticks, fleas and lice.

Tapeworms are the largest of the parasites that feed on the human body and can be up to 10 metres long! They have hooks and suckers to keep a firm hold on your intestine. Tapeworms don't have to worry about finding a mate. When they are reproductively mature, their end segment, which is full of eggs, along with their host's faeces moves on to its next host.

Did you get an itchy bottom at night when you were little? You probably had a roundworm infection such as threadworm or pinworm. Although these worms usually live in the large intestine, when ready to lay her eggs the female worm moves down to lay them on the moist, warm skin of your anus. The sticky material they are covered with irritates your skin so that you scratch it, picking up some eggs in your nails as you do. Better remember to wash your hands before you eat!

FIGURE 4.18 a. The head of a tapeworm showing its hooks and suckers **b.** A pork tapeworm with hooks that cling to the digestive track of their host.

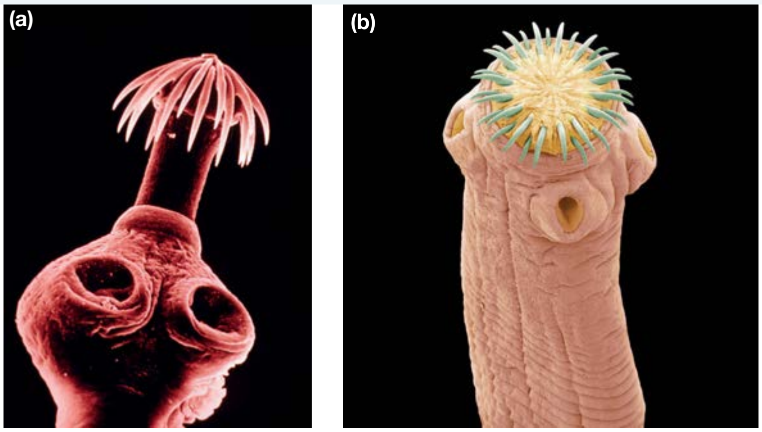


TABLE 4.1 Some common parasites that are also pathogens

Parasite	Condition caused	Source of infection
Amoeba	Amoebic dysentery	Contaminated food and drink
Malarial parasite	Malaria	Bite from infested mosquito
Tapeworm	Tapeworm	Raw or poorly cooked meats
Blood fluke	Schistosomiasis	Contaminated water
Tick	Skin infestation	Tick-infested areas
Louse	Pediculosis	Contact with human carrier, bedding, clothing
Flea	Skin irritation	Animal and human carriers

on Resources

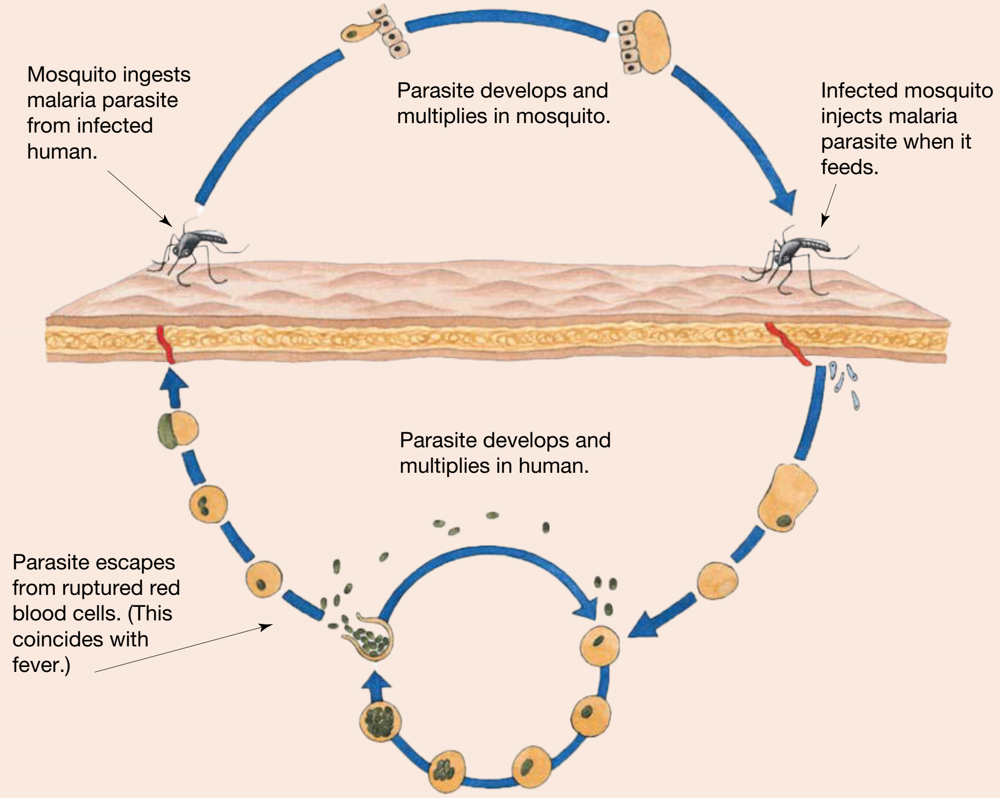
Video eLesson Human head lice on human hair (eles-2646)

CASE STUDY: Malaria

How do you catch malaria?

You catch malaria by being bitten by a female *Anopheles* mosquito that has been infected by the *Plasmodium* parasite. The parasite moves into the salivary glands of the mosquito and is passed into your bloodstream when it bites you.

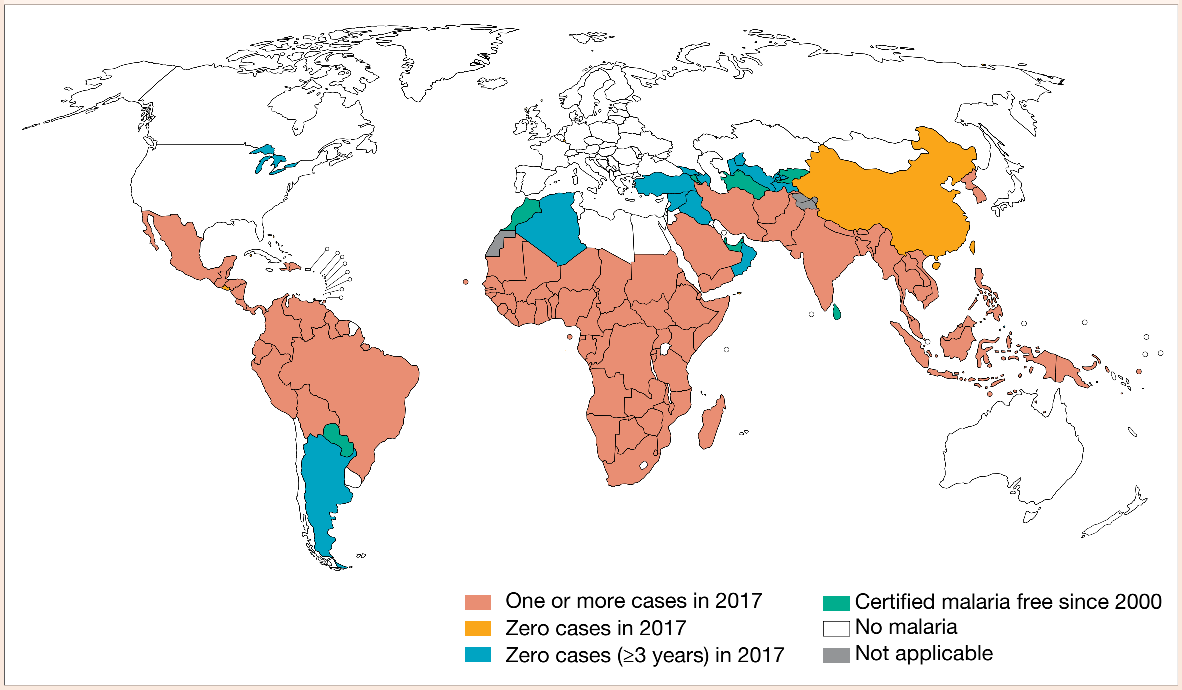
FIGURE 4.19 Malaria transmission cycle



How dangerous is malaria?

In 2017, the World Health Organisation estimated that malaria caused 435 000 deaths worldwide. It is one of the most serious public health problems worldwide. It is also a leading cause of death and disease in many developing countries, in which pregnant women and young children are most affected. An infected mother can transmit the malaria parasite to her unborn child through the placenta.

FIGURE 4.20 Countries with malaria are decreasing, but 92 countries and 3.4 billion people are estimated to be still at risk.



How do you know if you have malaria?

Most people have high fevers, aches, pains, shivering and night sweats. Fatigue, low blood-cell counts and yellowing of the skin and whites of eyes (caused by jaundice) may also result. Severe complications include cerebral malaria, anaemia and kidney failure, and can often result in death.

What causes malarial night sweats?

Once inside your body, malaria parasites grow and multiply first in your liver cells and then in your red blood cells. Successive broods of malaria parasites grow inside your cells until your red blood cells burst open and are destroyed. The new malaria parasites (or merozoites) seek other cells to infect and destroy. This causes night sweats.

What's new in malaria research?

In Australia, teams led by Professor Alan Cowman at the Walter and Eliza Hall Institute of Medical Research have studied how the malaria parasite uses genetic trickery to evade our immune systems. They have developed a novel class of compounds that target multiple stages of the parasite's life cycle, and is hoped will overcome existing drug resistance. In preclinical testing, the drug slowed growth of the parasite in the host, and also prevented transmission of the parasite back to mosquitoes.

Watch out for the mozzies!

Mosquitoes are not only vectors for the malaria parasite, but can also transmit elephantiasis, dengue fever, yellow fever and Japanese encephalitis.

on Resources

Video eLessons Malaria life cycle Part 1 (eles-4189)
Malaria life cycle Part 2 (eles-4190)

elog-0671

INVESTIGATION 4.1

Microbes

Aim

To investigate the types of microbes in the air of the laboratory

Materials

- prepared agar plate
- marking pen
- sticky tape

Background

Agar is a jelly-like material made from seaweed. It provides a source of nutrients for microbes.

Health and safety guidelines

Do not open the tape seals after incubation.

Method

1. Take the lid off the agar plate to expose the agar to the air in your laboratory for about 5 minutes.
2. Seal the lid on the agar plate carefully, using the sticky tape.
3. Give the plate to your teacher to incubate at about 35 °C for two days.
4. After two days examine your incubated plate and record your observations. *Note:* Do not open the plate seals.
5. Give the unopened plates back to your teacher for proper disposal.

Results

1. Sketch your plate again after it has been incubated for 2 days.
2. Describe the general appearance, colour, size and shape of the groups or colonies on the agar plate.

Discussion

1. What can you conclude about the air in your science laboratory?
2. Do you think that the air in other parts of your school would be different? Explain.
3. Discuss the risks that could be associated with the experiment and ways to reduce these risks.
4. Formulate your own question or hypothesis about microbial growth, and design an experiment that could be used to investigate it. Include an explanation of your choice of variables and required specific safety precautions.

Conclusion

What can you conclude about the microbes in your school laboratory?

on Resources

assess on Additional automatically marked question sets

4.3 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Distinguish between:
   a. pathogens, antigens and hosts
   b. prions, viruses and bacteria
   c. parasites, endoparasites and ectoparasites.
2. Our microbiome consists of trillions of microorganisms that live in us and on us. The bacteria that colonised the intestines after birth are important for development and function and are considered the normal flora of the gut. We depend on our gut bacteria to obtain vitamin K and vitamin B.
   a. Where do we obtain the bacteria that colonise our gut?
   b. Are any two people's gut microbiomes identical? Justify your response.
   c. Suggest factors that influence the composition of our gut microbiota over our lifetime.
3. Describe how our human microbiome protects us from pathogen attack. State five diseases that have been linked to the microbiome.
4. Compare the ways in which viruses and bacteria reproduce by placing *Yes* or *No* in the table.

Feature	Bacteria	Virus
Invade host cell to reproduce		
Reproduction results in new cells		
Contain DNA or RNA		
Can only reproduce inside host cell using host cell machinery		

5. a. State the cause of leprosy and describe how it is transmitted.
   b. Is leprosy curable today? Justify your response.
6. a. Explain why many biologists consider viruses to be non-living.
   b. Explain why the cell that is invaded by a virus is called a host cell.

Apply and analyse

7. Construct a cycle map to show how prions replicate.
8. Explain why most milk is pasteurised rather than sterilised.
9. Describe the relationship between mosquitoes and malaria. Is there a vaccine to protect against contracting malarial disease?
10. After taking medication, antibiotics, or being ill, people are often advised to eat yoghurt or other probiotics. Explain why yoghurt can be beneficial. Suggest some other foods that might be recommended and justify why.
11. The skin under your armpits contains over two million bacteria per square centimetre.
    a. Explain why they do not cause disease more often.
    b. Explain what would happen if the same bacteria entered your bloodstream through a cut.

Evaluate and create

12. Explain why it is a good idea to read up on protozoans before you travel to tropical climates.
13. Describe the most common illness suffered by overseas travellers.
14. Suggest practical methods for avoiding traveller's diarrhoea. Consider as many influences — such as drinking water, the impact of water on food production and food preparation — as you can.

Fully worked solutions and sample responses are available in your digital formats.

4.4 Historical medicine

LEARNING INTENTION

At the end of this subtopic you will be able to outline the medical beliefs of Ancient Greece and how they were developed and refined during the Middle Ages. You will also be able to recognise that the development of scientific theories and knowledge are based on previous observations and experiments.

SCIENCE AS A HUMAN ENDEAVOUR: Ancient medicine

Hippocrates and body humours

Before the invention of the microscope the causes of many infectious diseases were not only invisible, but also beyond our imagination. Without awareness of cells, other theories were developed to explain what we saw and what could not be seen.

Around 430 BC, the Plague of Athens killed one-third of the population of Athens. About 30 years later, a person who would have a considerable effect on our understanding of disease was born. His name was Hippocrates.

Hippocrates (circa 460–377 BC) was a Greek doctor who believed that everything was created from four elements: water, earth, air and fire. He also believed that linked to these elements were four humours within the human body. These were blood, yellow bile (choler), black bile (melancholy) and phlegm. He thought that these humours not only shaped a person's character but also, if unbalanced, could cause disease. Think about the word 'disease'. it is made up of 'dis' and 'ease'. The prefix 'dis' makes the opposite of the word that follows — not ease.

Hippocrates and his disciples looked for natural causes of disease. They based their medical practice on reason and experiment and used diet and medication to restore the body's balance of humours. Hippocrates also established the rules and principles that were followed by medieval doctors and are still followed by doctors today. The **Hippocratic Oath** requires doctors to take care of the ill and not do them harm.

FIGURE 4.21 Hippocrates (c. 460–377 BC) had a considerable impact on our understanding of disease.

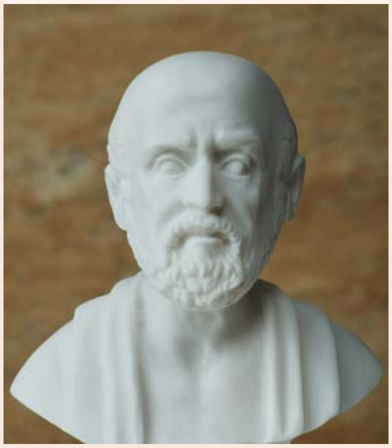


FIGURE 4.22 It was thought that body humours not only shaped a person's character but, if they were unbalanced, could cause disease.

Galen and anatomy

Claudius Galen (circa AD 129–199), a Greek physician who lived in Rome, was influenced by Hippocrates and developed his theories further. When he was in his late twenties (circa AD 157), Galen was appointed physician to gladiators in his home town of Pergamum. Within about 10 years he became the personal physician to Emperor Marcus Aurelius in Rome.

Galen believed that all diseases were caused by an imbalance in the elements or their associated body humours and that all cures must be based on correcting the imbalance. He also believed in the importance of anatomical knowledge. Galen wrote hundreds of books about human anatomy, surgery and herbal medicines — books that were to be used by doctors for the next thousand years.

Hippocratic Oath an oath historically taken by doctors that requires them to follow ethical rules and principles

SCIENCE AS A HUMAN ENDEAVOUR: The Middle Ages — Times of change

Beginning with the collapse of the Roman Empire, the Middle Ages (AD 500–1500) were a time in which Europe changed dramatically. This was a time of growing populations, developing technology, increased trade and new ideas. It was also a time of hardship, deadly disease and wars in which only about 50 per cent of children reached the age of 15; of those surviving, many died in their twenties and thirties.

FIGURE 4.23 In medieval times, astronomy was linked to body humours and treatment of disease.

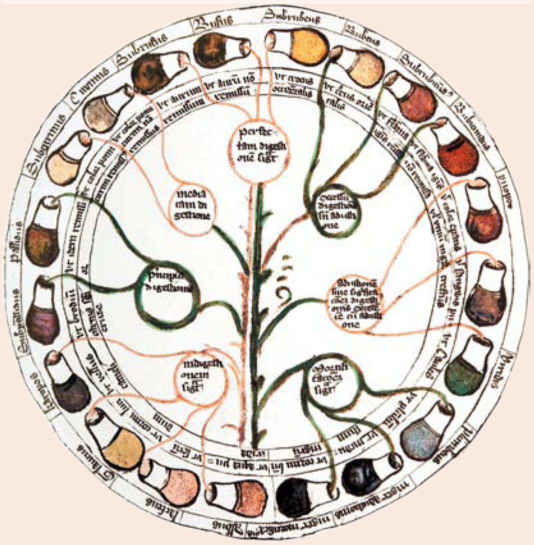
Causes of disease

Medieval doctors were influenced by the ideas of Hippocrates and also linked each of the four body humours to the stars and planets. However, medieval villagers relied on their own practical knowledge and traditional superstitions to explain causes of diseases, and used natural substances to create potions. There were also those who believed that evil spirits, curses or mysterious magical powers may be the cause of disease.

As the Christian Church grew more powerful, old superstitions were banned and traditional healers were controlled. Church leaders spread their own view of the cause of illness — God's punishment for sins. The Church also offered several different methods of spiritual healing, including prayers, charms, relics and pilgrimages.

Leprosy was a common disease in medieval Europe. This disease destroys skin, muscle and bones and was thought to be punishment from God. Not only were lepers treated with fear and loathing, but they were also not allowed to marry, had to carry a warning bell and were often driven out of villages.

FIGURE 4.24 A fifteenth-century diagram showing possible colours of urine to help doctors diagnose diseases



Medieval medicines

Medieval physicians advised their patients how to live healthy lifestyles, and used their training in mathematics and astronomy to map out healthy and sickly times. They also worked closely with apothecaries, who sold medicinal plants. Sometimes these plants and the apothecaries' knowledge of the four humours, astronomy, chemical sciences and religion were used to create medicines.

Medieval women made many of their families' medicines. They used seeds, stems and leaves of herbs, trees and flowers. Some medicines even used animals or animal products.

Diagnosing disease

Many medieval physicians considered that testing 'the waters' (urine) was an effective method in the diagnosis of disease. Scribes would note the colour, cloudiness or sediment of the urine and charts were used to match these features to particular diseases (see figure 4.24). Sometimes blood samples were collected, which may have been tasted to detect a diagnostic sweetness or bitterness.

Treating disease

Medieval barbers not only cut hair and shaved men's faces but also performed minor surgery, such as removing rotten teeth and bloodletting. The red and white striped pole often associated with barbers was a symbol that they let (released) blood, with the white stripes representing the bandages over the cuts.

Not only barbers were involved in bloodletting — this widespread medieval treatment was also performed by doctors and surgeons and was meant to improve the balance of humours within the body. Medical texts of the time showed which veins to cut to release each humor and cure different illnesses. Leeches were also applied to the skin to suck out poisons or bad blood from wounds.

Surgeons also used cupping and cauterising to treat disease. Cupping involved placing hot metal glasses or cups on a patient's cut skin, in the belief that poisons would be released from the body into the cup. To cauterise wounds or help heal internal disorders, surgeons would burn the tissues with red-hot irons or boiling oil.

FIGURE 4.25 A thirteenth-century anatomical illustration

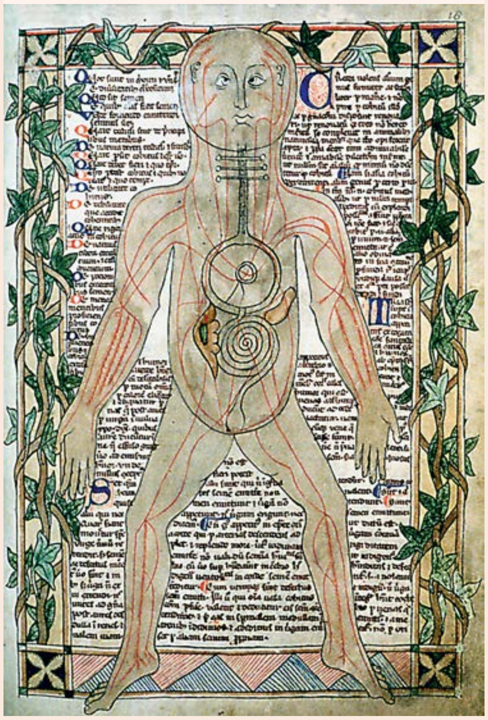


FIGURE 4.26 Bloodletting (left) and leeches (right) were used to treat diseases during medieval times.

SCIENCE AS A HUMAN ENDEAVOUR: Scientific understanding

Our knowledge and understanding of our world is shaped by what we can sense about it. While some of the ideas of those living in early Greece and medieval times may seem silly or strange to us, they made sense of their world with the tools that were available to them at the time.

The models, theories, knowledge and experiments of early scientists have allowed our scientific understanding to increase. The more we understand about science, the better we can use science to understand the world and develop new technologies. These technologies, which were unavailable to early Greek and medieval humans, provide us with an awareness of our world and the opportunity to explore it. Although we shape technology to meet our needs, we are also shaped by it.

on Resources

assess**on** Additional automatically marked question sets

4.4 Exercise

learn**on**

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Doctors take the Hippocratic Oath, vowing to take care of the sick and do no harm.
   a. Who was Hippocrates? Explain why is he important to our understanding of disease?
   b. Suggest any issues that are related to all doctors taking the Hippocratic Oath.
2. Complete the table, listing the four humours of which the body was thought to be made up of, and the corresponding elements to which they were thought to be linked.

Humour	Corresponding elements

3. Describe Galen's beliefs about the cause of disease.

Apply and analyse

4. Suggest why Galen's books were used for a thousand years to train doctors, rather than new books being written and used.
5. a. What did medieval people think caused disease?
   b. Did the practices of making people with leprosy carry a warning bell and driving affected people out of villages minimise the spread? Explain why or why not?
6. Describe what many medieval medicines were made of. Explain their functions.

Evaluate and create

7. Describe how medieval doctors used body humours to:
   a. diagnose disease
   b. treat disease.
8. Are leeches still used today in any medical procedures? Explain your answer.
9. If you had lived during the Middle Ages, what connections do you think you would have made about the cause and effects of disease? Why?

Fully worked solutions and sample responses are available in your digital formats.

4.5 Zooming in — microscale and nanoscale

LEARNING INTENTION

At the end of this subtopic you will be able to describe how the invention of the microscope led to the development and refinement of a number of scientific theories and discoveries. You will also be able to provide examples of how nanotechnology is helping scientists to develop better treatments for disease.

SCIENCE AS A HUMAN ENDEAVOUR: Scientific advances due to the microscope

The invention of the microscope opened a whole new world to explore and led to changes in how we saw and thought about not only the world, but also ourselves!

Hooke and cells

The microscope was invented in 1609. Scientists began to develop new ideas rather than relying on those in Greek and Roman texts. In 1665, a bubonic plague epidemic in London killed 75 000 people. It was also during this year that an English physicist, Robert Hooke (1635–1703) observed a sliver of cork under the light microscope and noted a pattern of tiny regular holes that he called **cells**. Later that year, Hooke published his book of microscopic drawings called *Micrographica.* His recorded observations led to many discoveries in related fields.

FIGURE 4.27 Hooke's *Micrographia* (1665) and van Leeuwenhoek's *Arcana naturae* (1695)

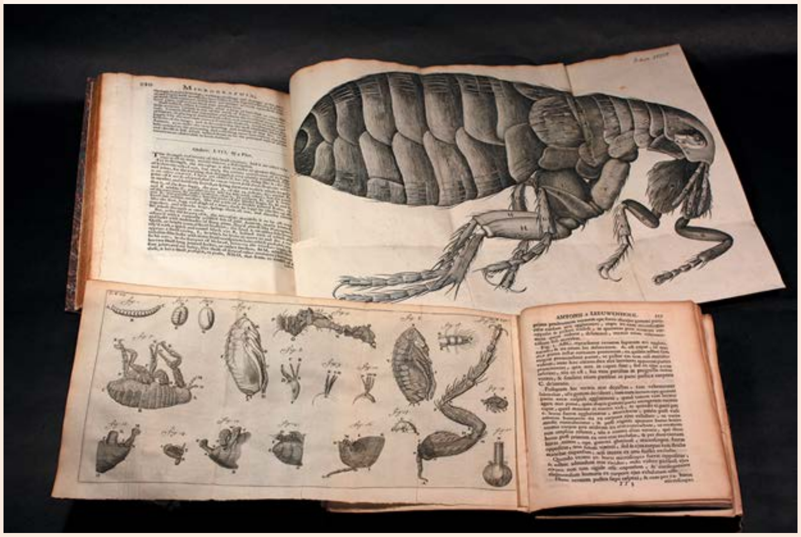


FIGURE 4.28 Robert Hooke observed a sliver of cork under his microscope and noted cells.

cell the smallest unit of life and the building blocks of living things

Leeuwenhoek and cells

In 1674, Anton van Leeuwenhoek (1632–1723) observed 'animacules' in lake water through a ground glass lens. Although this marked the beginning of the formal study of microbiology, little progress was made for over a century. A possible reason for this was because few could equal his skill in grinding lenses to the accuracy required for simple microscopes. It was not until the mid-19th century that technological advances in optics led to the production of compound microscopes that did not produce distorted images.

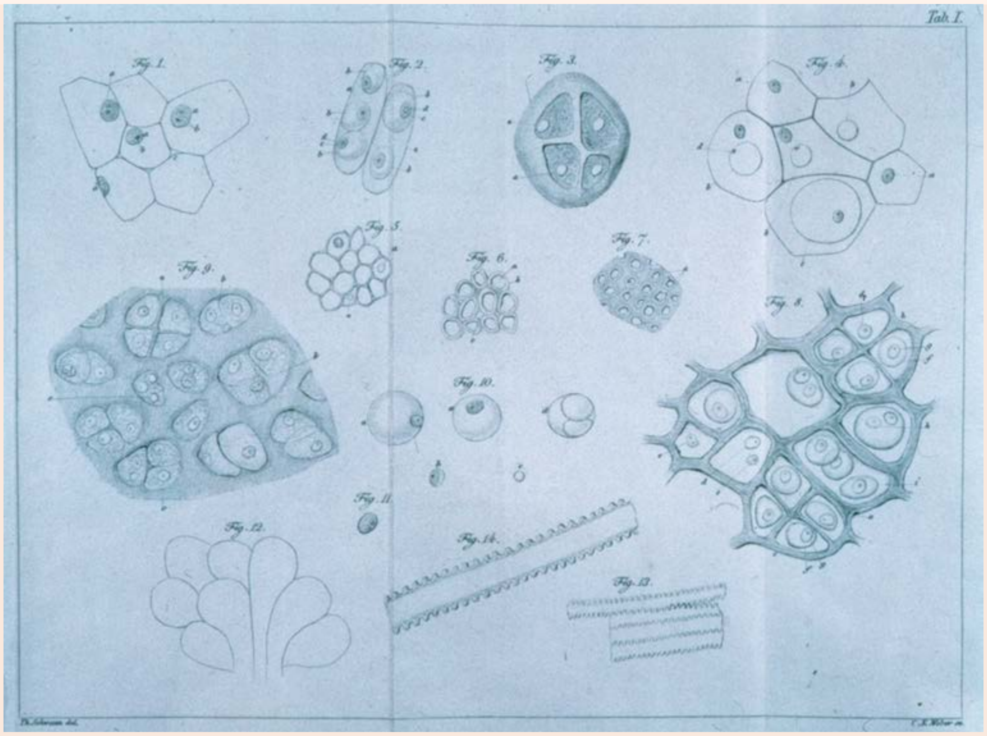
FIGURE 4.29 Anton van Leeuwenhoek

Schleiden and Schwann — Cell theory

In 1838, Matthias Schleiden suggested that plants were made up of cells and Theodor Schwann recognised that animals were also composed of cells. This led to the establishment of the cell theory — that all living things are made up of cells.

FIGURE 4.30 Theodor Schwann and Matthias Schleiden

FIGURE 4.31 Sketches of cells made by Theodor Schwann



Pasteur and Koch — Germ theory

Between 1857 and 1880, Louis Pasteur (1822–1895) performed a series of experiments that disproved the doctrine of spontaneous generation — the notion that life could arise out of non-living matter. Until Pasteur's work, it was thought that microbes were produced only when substances went rotten. Pasteur showed that microbes were around all the time and could cause disease. He also introduced vaccines for fowl cholera, anthrax and rabies that were made from altered or weakened strains of viruses and bacteria.

In 1867, Joseph Lister published a study associating micro-organisms with infection. This led to the use of disinfectants during surgery, reducing post-operative infections and death. In this same year, Robert Koch (1843–1910) established the role of bacteria in anthrax and formulated postulates that could be used to confirm whether the cause of an infection was viral or bacterial. Eight years later, in 1875, his postulates were used for the first time to demonstrate that anthrax was caused by *Bacillus anthracis.* This validated the germ theory of disease.

Virchow — Body humours out of favour

In 1858, Rudolf Ludwig Carl Virchow (1821–1902) argued that all cells arose from pre-existing cells and that the cell, rather than body humours, was the ultimate locus of all disease. His paper *Cellular Pathology* established the field of cellular pathology, linking cells and disease.

FIGURE 4.32 Rudolf Virchow argued that cells rather than body humours were the locus of all disease.

With the availability of microscopes providing more detailed observations, scientists continued to make many more discoveries. With these observations, new theories were generated. More pathogens were identified as being the cause of infectious diseases and vaccines for specific diseases were developed.

Knowledge of cells leads to discovery of our immune response

In 1884, Élie Metchnikoff (1845–1916) discovered **white blood cells** that showed antibacterial activity and called them **phagocytes**. He then formulated the theory of **phagocytosis** and developed the cellular theory of vaccination. In 1891, Paul Ehrlich (1854–1915) proposed that **antibodies** were involved in **immunity**. In 1949, Australian Frank Macfarlane Burnet began research that led to the **clonal selection theory** and, in 1961, Noel Warner established the physiological differences between **cellular** and **humoral immune responses**. In 1974, another Australian, Peter Doherty, together with Rolf Zinkernagel, discovered the basis of identifying self and non-self that is necessary for immunity. This was just the beginning of many new discoveries to be made regarding how we fight disease.

white blood cells living cells that fight bacteria and viruses

phagocyte white blood cell that ingests and destroys foreign particles, bacteria and other cells

phagocytosis the ingestion of solid particles by a cell

antibodies any of various proteins that are produced by B lymphocytes as a result of the presence of a foreign substance in the body and that act to neutralise or remove that substance

immunity resistance to a particular disease-causing pathogen

clonal selection theory a model for how the immune system responds to infection and how certain types of B and T lymphocytes are selected for destruction of specific antigens invading the body

cellular immune response immunity involving T lymphocytes (assisted by phagocytes) that actively destroy damaged cells or cells detected as non-self, such as those triggering an immune response

humoral immune response immunity involving antibodies (which are specific to a particular antigen) that are produced and secreted by B lymphocytes that have differentiated into plasma cells

DISCUSSION

Some disease research has involved using human subjects without their consent. Other research has put the subject at great risk. Do you ever think scientists should be allowed to research on humans without their consent? What about if they use tissue samples from deceased people?

SCIENCE AS A HUMAN ENDEAVOUR: Knowledge — A powerful weapon against disease

The development of new technologies has enabled us to expand our senses and magnify the world around and within us. With these new observations came many new discoveries, prompting new ways of thinking and many new theories to identify the causes of disease and how the diseases could be prevented, treated or cured. Often the drive for these discoveries was the devastation and despair associated with the effects of disease within the society in which these scientists lived.

In 1909 Paul Ehrlich introduced the idea of 'magic bullets' — chemicals that could destroy bacteria without harming the host. In 1928 Alexander Fleming (1881–1955) discovered the **antibiotic** penicillin — opening the era of 'wonder drugs'. In 1941, Australian Howard Florey (1881–1955) effectively showed that penicillin killed *Strepococcus* bacteria and persuaded companies to manufacture the antibiotic, saving millions of lives.

antibiotic a substance derived from a micro-organism and used to kill bacteria in the body

New vaccines have been developed against many diseases, saving lives and reducing suffering. Understanding of our body systems and how we fight disease led to new discoveries and technologies. New technologies would often give rise to many other new technologies.

In 1959, Sydney Brenner and Robert Horne developed a method for studying viruses at the molecular level using the electron microscope. Such technologies enhanced our senses and enabled us to observe and be aware of our environment in a way we could never previously have imagined. What future discoveries will new technologies allow us to make? Will our descendants consider our current theories in the same way that we now consider those of Hippocrates, Galen and those who lived in medieval times?

SCIENCE AS A HUMAN ENDEAVOUR: Getting smaller — The nanoscale

Just when we thought we knew it all, the development of nanotechnologies has enabled us to see even smaller! With our new vision came another world to explore, another journey of discovery, excitement and questions … and possible new ways to protect ourselves against disease.

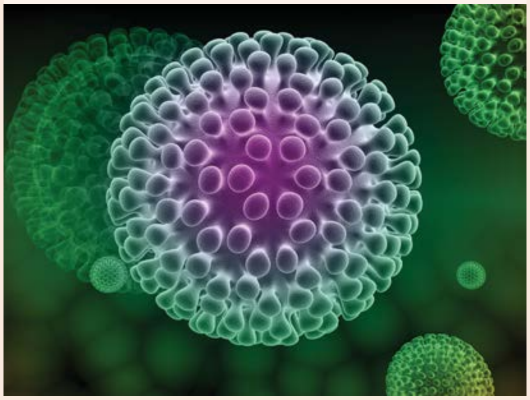
When we talk about cells, we usually talk in terms of **micrometres** (μm) (a millionth of a metre, or $\frac{1}{1000000}$ m).

When we talk about nanotechnology, we need to think in **nanometres** (nm). A nanometre is one billionth of a metre, or $\frac{1}{1000000000}$ m.

To understand nanotechnology and nanoscience, you need to learn to think very, very small.

While nanotechnology is about the very small, its implications and potential application are enormous. The development of this technology has given us not only super-smart and super-strong materials and medicines, but also the possibility of creating other technologies that are currently not possible for mainstream production.

FIGURE 4.33 On the flu virus's surface there are only two types of proteins: haemagglutinin and neuraminidase.



micrometre one millionth of a metre

nanometre one billionth of a metre

Using models to understand the nanoscale

We are in a time of biological revolution. One of the current questions for scientists to investigate involves the mysteries of viruses that are a current or potential threat to members of our species or species important to us.

Scientists often use models to help them visualise the features of their studies. They may even add colour to different parts to emphasise features or chemical composition. These models can be representations of the types and arrangements of atoms or molecules in a virus. Aside from helping scientists visualise their shapes, models also enable them to predict how viruses may interact with the cells in the human body. This may provide clues as to what we can do or create to protect us from attack.

Using nanotechnology to cure disease

Nanobots

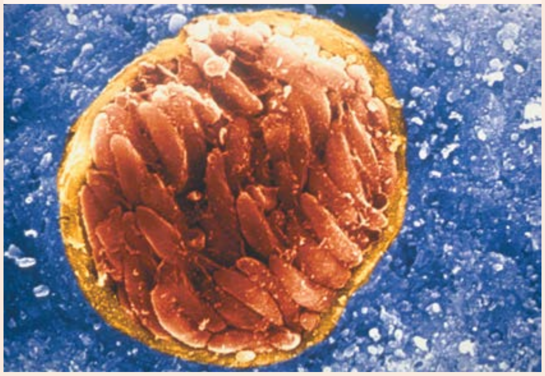
In the future, nanomedicine may help cure some diseases through the combination of nanotechnology with biotechnology.

Nanotechnology may make possible the creation and use of materials and devices working at the level of molecules and atoms. Imagine minuscule machinery that could be injected to perform surgery on your cells from the inside. They could be programmed to seek out and destroy invaders such as bacteria, protozoans or viruses, or even cancerous cells. Heart attacks due to the blockage of your arteries may also be a thing of the past. These nanobots may be able to cruise through your bloodstream to clear plaque from your artery walls before it has a chance to build up. Could these nanobots also be programmed to stop us from growing old?

Gold nanoparticles kill brain parasite!

Toxoplasmosis gondii is a parasite that causes cysts in the brain of about a third of the people it infects. Michael Cortie, an Australian scientist, has developed a technique that involves the use of gold nanospheres (about 20 nm in diameter) that are coated with an antibody that selectively attaches to the parasite. When a laser is applied, the nanospheres heat up and kill the parasite. This is groundbreaking research and may have further applications related to other parasites.

FIGURE 4.34 This electron micrograph shows a cyst from a human brain that has been infected with the parasite *Toxoplasmosis gondii*.



Drug delivery

Tiny human-made **nanoparticles** (about 0.1–100 nanometres) are small enough to pass through a cell membrane. They are currently being developed to deliver drugs directly to cancer cells. The basic structure of nanoparticles is called a **dendrimer**. Attached to these cancer-fighting dendrimers are methotrexate, folic acid and a fluorescent stain. Methotrexate is a drug that kills the cancer cells and the fluorescent stain allows monitoring of the process. Folic acid acts as the bait to attract the cancer cells. This vitamin is essential in cell reproduction and, as cancer cells are actively multiplying, they have a high need for it. When they accept the nanoparticle, the methotrexate poisons the cell, killing it. These dendrimers are then removed from the bloodstream as they pass through the kidneys.

Other scientists are using fragments of bacteria to carry drugs to tumor cells. EnGeneIC in Sydney have been involved in the development of a new technique that uses fragments of bacteria (such as *Salmonella enteric* and *E. coli*) called 'EnGeneIC Delivery Vehicles' (EDVs) to carry drugs to tumour cells, resulting in a potential treatment that is more potent but less toxic than current chemotherapy treatments. Once these little biorobots have unloaded their cargo, the tumour cells are destroyed.

Rational drug design

Viruses enter the cells of their host to use the cell's machinery to replicate themselves. This makes it difficult to develop drugs to kill them without killing their host's cells as well. Knowledge of the structure of the virus and how it replicates has provided scientists with information enabling them to design and develop drugs that can be used to reduce infection.

Some antiviral drugs inhibit DNA or protein synthesis and hence interfere with the replication of the virus within the cell. Interferon, for example, stops protein synthesis, and idoxuridine interferes with DNA synthesis. Some other antiviral drugs interfere with specific enzymes that are important to the virus.

Relenza is an example of an anti-influenza drug that was researched by Australian CSIRO scientists. Relenza binds to the active site of neuraminidase, one of the proteins on the protein envelope of the influenza virus. This action prevents new viral particles from being able to leave the infected cell to infect other cells.

nanoparticle a microscopic particle about 0.1–100 nanometres in size

dendrimer a molecule that forms the basic structure of a nanoparticle

DISCUSSION

While some see nanotechnology as the technological saviour of the twenty-first century, others are concerned. Nanotechnology operates at the scale of atoms and molecules. It is fundamentally different from current technologies in that it builds from the bottom up. The underlying principle of nanotechnology is both disturbing and mesmerising — if you can control and rearrange atoms, you can literally create anything! What are our boundaries and responsibilities, or don't we need or want any?

on Resources

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4.5 Exercise

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Select your pathway

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

Remember and understand

1. Complete the following table with the scientist's contribution to their discovery of disease.
   A. Developed a method for studying viruses at the molecular level using the electron microscope
   B. Discovered the basis of identifying self and non-self that is necessary for immunity
   C. Began research that led to the clonal selection theory
   D. Discovered the antibiotic penicillin
   E. Effectively showed that penicillin killed *Streptococcus* bacteria. He persuaded companies to manufacture the antibiotic, saving millions of lives.

Scientist	Contribution to the scientific knowledge of disease
a. Frank Macfarlane Burnet	
b. Peter Doherty	
c. Alexander Fleming	
d. Howard Florey	
e. Sydney Brenner and Robert Horne	

2. Identify the contributions to the scientific knowledge of disease by the following scientists:
   a. Robert Hooke
   b. Anton van Leeuwenhoek
   c. Theodor Schwann
   d. Louis Pasteur
   e. Élie Metchnikoff
3. Using the table of scientists, match which theory they contributed to from the below list:
   A. Cells and cell theory
   B. Germ theory
   C. Cells cause disease and are involved in the immune response
   D. Antibiotics for treatment of bacterial infection
   E. Structure of viruses

Scientist	Contribution to the scientific theory
a. Robert Hooke	
b. Peter Doherty	
c. Louis Pasteur	
d. Howard Florey	
e. Sydney Brenner and Robert Horne	
f. Élie Metchnikoff	
g. Frank Macfarlane Burnet	
h. Alexander Fleming	

Apply and analyse

4. **a.** Calculate how many micrometres (μm) there are in 2 metres.
   b. Calculate how many nanometres (μm) there are in 0.5 metres.
5. Explain how the use of nanotechnology has contributed to the cure of a disease? Use any particular disease to answer this question.
6. SIS Robert Hooke invented a microscope and viewed a sample of cork. He called the regular holes he saw 'cells'. This is the name we still use today to define the smallest unit of an organism. Was what Hooke observed in the cork sample really a cell? Draw on your knowledge of the structure of plant cells.
7. Explain how the knowledge of cells leads to discovery of our immune response.

Evaluate and create

8. Relenza is an example of an anti-influenza drug that was researched by Australian CSIRO scientists. Describe how it prevents a virus from spreading.
9. Give an example of rational drug design.

Fully worked solutions and sample responses are available in your digital formats.

4.6 Outbreak

LEARNING INTENTION

At the end of this subtopic you will be able to understand how epidemics and pandemics have shaped human history and why the world's population is more vulnerable to infections than in earlier times.

4.6.1 Epidemics and pandemics

Disease has shaped our human history. It could be argued that we are who we are because of and in spite of disease.

Throughout history there have been records of **plagues** — contagious diseases that have spread rapidly through a population and resulted in high death rates. There are also other terms used to describe the spread of disease. **Epidemics** occur when many people in a particular area have the disease in a relatively short time and **pandemics** are diseases that occur worldwide.

plagues contagious diseases that spread rapidly through a population and results in high mortality (death rates)

epidemic a disease affecting a large number of people in a particular area in a relatively short period of time

pandemic a disease occurring throughout an entire country or continent, or worldwide

The Black Death — Bubonic plague

The Plague of Justinian in the sixth century was one of the first recorded pandemics. It is thought to have been the result of **bubonic plague**. Of all of the plagues throughout history, the bubonic plague (known as the **Black Death** in Europe) has been the most widespread and feared. Its name is due to the presence of black sores on the skins of victims. The cause of the disease is the bacteria *Yersinia pestis*. These bacteria were transmitted by fleas that had bitten an infected rat and then bitten a human, infecting the human with the disease.

First recorded in the north-eastern Chinese province of Hopei in 1334, it is thought that bubonic plague was responsible for the death of about 90 per cent of its population (about 2 million people). By 1348, bubonic plague had reached Europe. Within 5 years, an outbreak of this disease had resulted in the death of almost one-third of Europe's population. After this time, plague visited England another six times before the end of the century.

Nearly all those infected died within 3 days of their first symptoms appearing. Lack of medical knowledge and great fear resulted in the development of a diverse range of methods being used to fight the condition. Some people tried special diets or were cut or bled in the hope that the disease would leave their bodies with their bodily fluids. Others (flagellants) whipped themselves to show their love of God, hoping to be forgiven their sins and spared the disease. Most importantly, bodily wastes and the bodies and clothes of those infected with the disease were burned in deep pits. In some areas, improved public sanitation resulted from these outbreaks.

The last recorded epidemic of the Black Death was around 1670. A victim of its own success, it had killed so many so quickly that those remaining had either immunity or genetic resistance. While it could still infect, its hosts were able to fight back and destroy it. Its demise paved the way for another disease, smallpox, to take over as the number one infectious disease.

FIGURE 4.35 Plague doctors wore protective clothing that included a long beak filled with antiseptic substances.

FIGURE 4.36 The bacteria causing the Black Death was transmitted by fleas

4.6.2 Crossing boundaries

Recent years have seen not only the discovery of new infectious agents, but also the emergence of some of our old infectious enemies. Some of these new diseases are crossing the species barrier and are now infecting species that they previously did not affect. Increasing resistance of many pathogens to antibiotics or vaccines has also raised concerns about the potential for sudden outbreaks of infectious diseases around the world.

Some of the new diseases and pathogens that have been identified or crossed the species barrier over the last few decades include Lyme disease, rabies, henipavirus, bovine spongiform encephalopathy (mad cow disease), Legionnaire's disease, HIV, Marburg virus, hantavirus, SARS, H5N1, Ebola virus and SARS-CoV-2 (the virus that causes COVID-19).

bubonic plague an infectious, epidemic disease, caused by the *Yersinia pestis* bacteria and carried by fleas from rats; also known as the Black Death

Black Death *see* bubonic plague

EXTENSION: New diseases mark the start of a new geological era

Increased travel between continents brought new knowledge and discoveries. It also brought death. At the turn of the century, around 1500 expeditions by Columbus and other explorers brought venereal diseases, smallpox and influenza to areas that had no prior history of them. This resulted in the deaths of millions of native people, who had no prior exposure to enable them to develop immunity. In some areas, up to 95 per cent of the native population died. This drop in population from introduced diseases was so significant it can be seen in a global fall in carbon dioxide levels around the globe (as preserved in Antarctic ice core records). Carbon dioxide levels fell so significantly because farming across the American continent nearly stopped entirely, which resulted in re-growth of forests, which in turn consumed more carbon dioxide. This event is recognised globally and has been suggested to mark the start of a new geological era known as the Anthropocene — the age of man.

FIGURE 4.37 The diseases brought by explorers resulted in millions of deaths.

4.6.3 Viral diseases

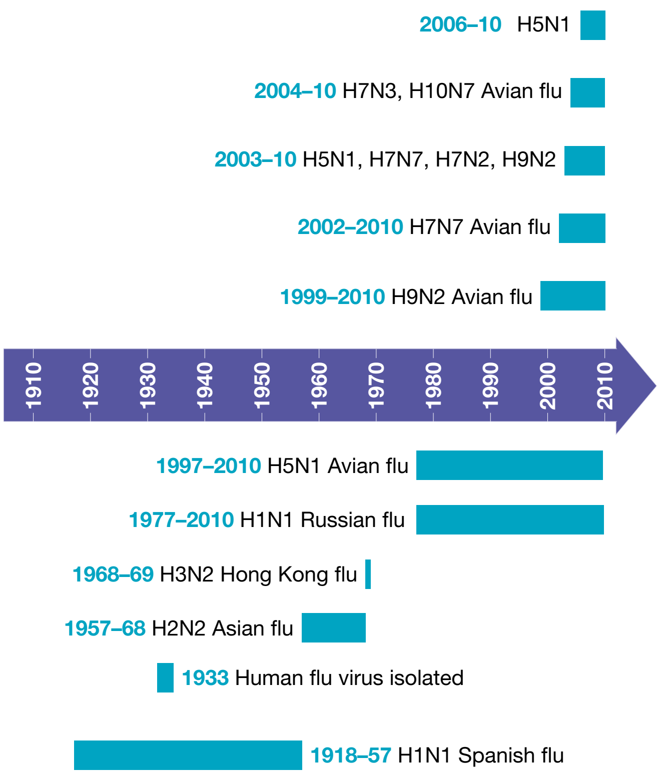
Why are viruses so effective at infecting large populations? Let's consider some of the major viruses that have affected the world in modern times.

Influenza

Throughout history, there have been numerous outbreaks of influenza. The influenza virus constantly evolves, and pandemics happen every few decades when the flu virus gets new **surface proteins** that people have little immunity to, generally because they come from an animal strain.

By the end of 1918, more than 25 million people had died from a virulent strain of **Spanish influenza** (H1N1). In 1919, the Health Organisation of the League of Nations was established, with the aim of preventing and controlling disease around the world.

FIGURE 4.38 A timeline of influenza outbreaks



surface protein a protein molecule occurring on the surface of a virus

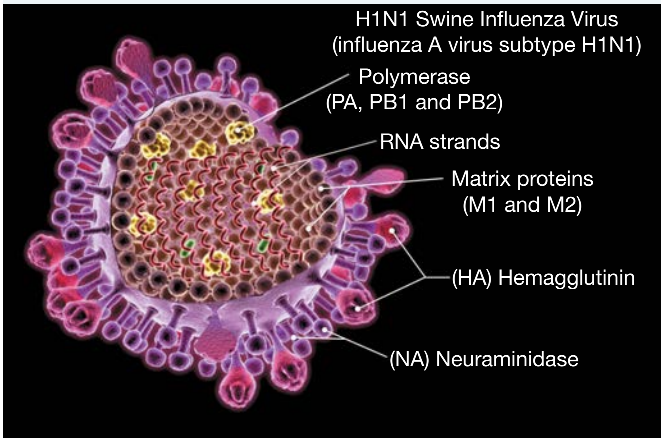
Spanish influenza a strain of influenza caused by the H1N1 subtype of influenza virus, which spread across the world in 1918–1920

The **Asian influenza** (H2N2) pandemic emerged in 1957, followed by a series of others over the next decades. **Avian influenza** (H5N1) made its debut in 1997 in a form that was highly contagious among birds and also infected humans. Since that time, it has devastated East Asian poultry industries. By 2006, a particular strain of H5N1 had been transmitted to humans and had caused a number of fatalities. H5N1 was dangerous because its H5 surface protein was totally new to humans — this is why it has killed more than half of the people who have been infected with it.

Swine flu

In 2009 there was a **swine flu** (H1N1) pandemic, which killed several thousand people. This strain of influenza contained a mixture of genes from the swine flu, human flu and avian flu viruses. It was of particular concern because it was thought that this new strain might have surface proteins that the human immune system may not recognise.

FIGURE 4.39 The swine flu (H1N1) virus contains a mixture of genes from the swine flu virus, human flu virus and avian flu virus.



Asian influenza a strain of influenza caused by the H2N2 subtype of influenza virus, which spread across parts of the world in 1956–58

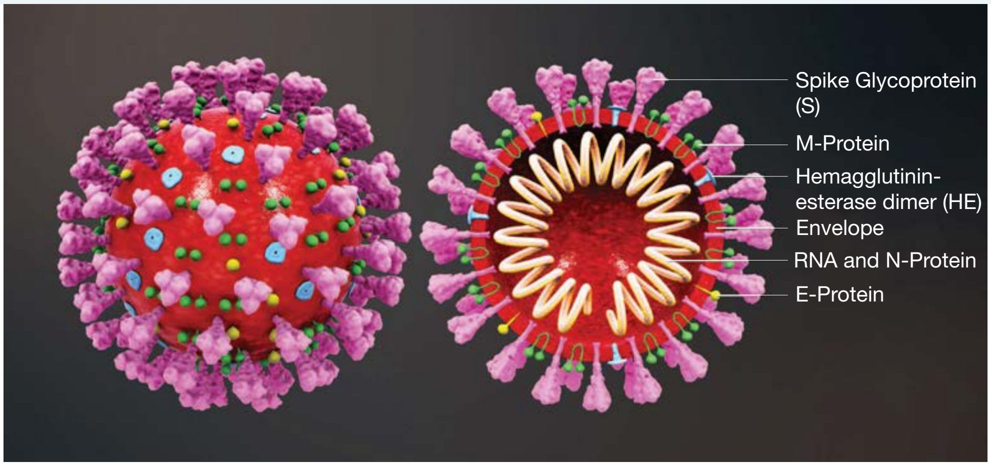
avian influenza a strain of influenza caused by the H5N1 subtype of influenza virus that is highly contagious in birds and has caused over 300 fatalities in humans since 2003

swine flu a strain of influenza caused by the H1N1 subtype of influenza virus, containing a combination of genes from the swine, human and avian flu viruses

Coronaviruses

Coronaviruses are named for the 'corona' or crown of spikes on their viral envelope, which gives them their characteristic shape. These spikes bind to specific receptors on the host cell. Coronaviruses have a strand of RNA surrounded by a viral envelope with spike proteins. In humans and some other animals, coronavirsuses cause respiratory tract infections. They were first discovered in the 1930s in a respiratory tract infection in domesticated chickens.

FIGURE 4.40 Morphology of a coronavirus



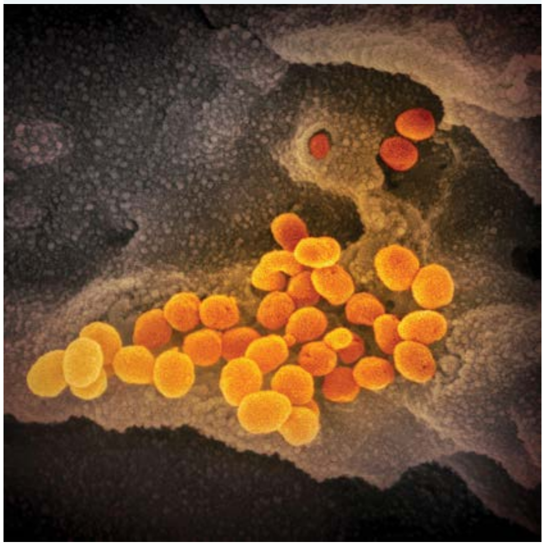
There have been three coronaviruses that have produced severe symptoms in humans.

1. SARS-CoV: Severe Acute Respiratory Syndrome Coronavirus — During 2002–2004 this virus infected around 8000 people, with a mortality rate of approximately 10 per cent. In 2017, scientists traced the cause of the virus from a population of horseshoe bats in China, which passed the virus through the intermediary species of civets (a small, norturnal mammal native to Asia and Africa), and then on to humans. No cases have been recorded since 2004.
2. MERS-CoV: Middle East Respiratory Syndrome-related Coronavirus — Another virus throught to have originated in bats, humans are typically infected through contact with camels or camel products. Spread between humans is not common, and requires close contact. Between its discovery in 2012 until 2020, there have been approximately 2500 cases, but has a mortality rate of 35 per cent. There is currently no vaccine.
3. SARS-CoV-2: Severe Acute Respiratory Syndrome Coronavirus 2 — This is the virus that causes the coronavirus disease 2019 (COVID-19). It has spread to be recognised as a global pandemic and the World Health Organization (WHO) has designated it a Public Health Emergency of International Concern. Initial scientific investigations suggest it has an animal origin due to its genetic similarity to bat coronaviruses, and may have passed through pangolins as an intermediate species in its spread to humans. China was the first country to report the disease to the WHO in late December 2019, and it is currently thought to have originated in Wuhan, China, in people working in a market. By August 2020, there were over 22 million confirmed cases of COVID-19 around the world, and the mortality rate is thought to be less than 5 per cent. While it is thought to cause less severe illness in the majority of cases, compared to SARS-CoV, it appears to be much more infectious.

   The shape of SARS-CoV-2 is much like other coronaviruses, and it is approximately 50–200 nanometres in diameter. It has four structural proteins as shown in figure 4.40. The spike protein is what allows it to attach to the cell membrane of the host cell. The virus is thought to infect a patient by the following:
   - An infected person expels droplets with the virus and they are absorbed through the mucus membranes (inhaled, or perhaps even through touching the eyes or mouth)
   - Cells in the nose have a cell-surface receptor called ACE2, which the virus attaches to and then enters the cell, and starts making many copies of itself. Although they are infectious, patients may not even have symptoms at this point, or they may develop a fever, dry cough, sore throat or a loss of smell and taste.
   - If the body does not fight off the invading virus at this point, it moves down the windpipe and enters the lungs. The tiny airsacs in the lungs (the alveoli) are lined with a single layer of cells that are also rich in ACE2 receptors. The virus populates the alveoli and the patient can struggle to breathe.

FIGURE 4.41 Pangolins are scaly-skinned mammals found in Asia and Africa. They are classified as Vulnerable to Critically Endangered.

FIGURE 4.42 A scanning electron microscope image of SARS-CoV-2 (orange) emerging from the surface of cells (grey) cultured in a laboratory

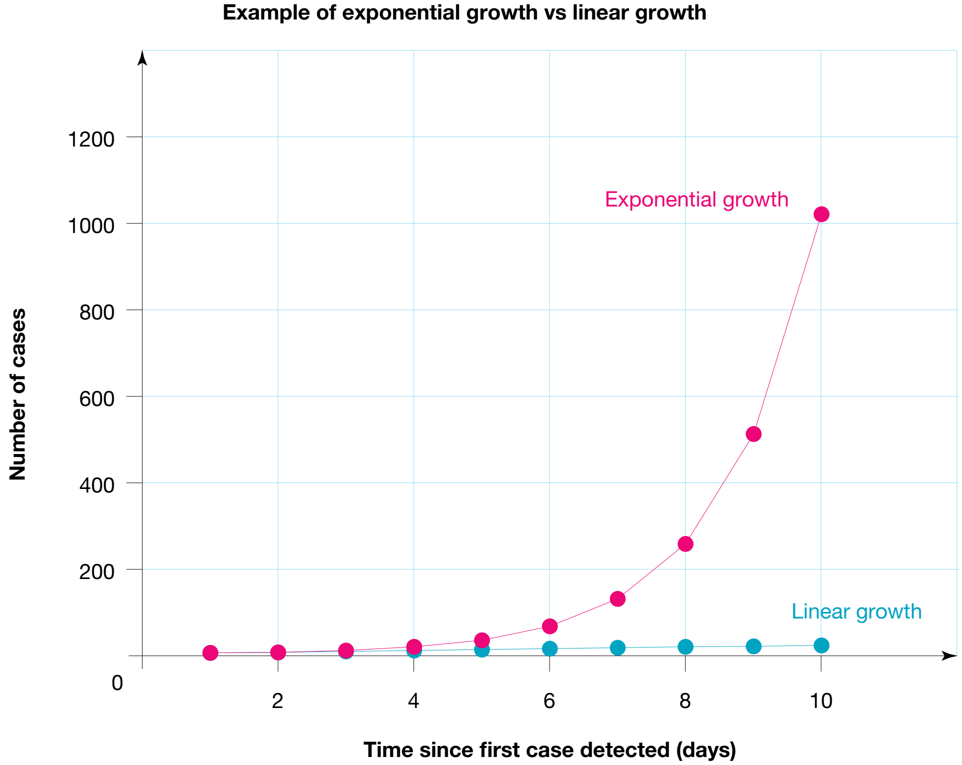


- White blood cells try to fight off the virus, and encourage more immune cells to grow, killing the virus but leaving fluid and dead cells (pus) in the lungs, which can fill the lungs and leave patients struggling to breathe.
- In severe cases the immune system overreacts to the virus causing a 'cytokine storm' and the immune system starts to attack healthy cells. Blood pressure drops, blood vessels leak and blood clots form, which can lead to severe damage to, and even failure of, other organs such as the heart, liver, kidneys, and intestines.

These severe symptoms require high levels of care in hospitals, and that is why the world's population was placed under instructions to minimise physical contact, to ensure hospitals were not overwhelmed by severe cases of COVID-19. This public health strategy became known as 'flattening the curve' of new infections. Due to the infectiousness of this virus, the curve of new infections could be defined by a mathematical phenomenon known as exponential growth, where infections were doubling every three days.

Exponential growth is difficult to visualise. The graph at figure 4.43 compares linear growth and exponential growth.

FIGURE 4.43 A comparison of **a.** exponential growth and **b.** linear growth



The World Health Organization has identified a likely series of steps that allow viruses to spread across the world:

- An influenza virus in birds or animals develops the ability to infect humans and cause serious disease. Humans need close contact with animals for this to occur.
- The virus mutates (changes its genetic makeup), which allows it to pass from human to human.
- The virus is able to transmit readily between humans because of its short incubation period and how easily it can be spread (contact with body fluids, coughing sneezing etc.). As we saw with COVID-19, rapid global spread occurs through international travel.

Since the emergence of the virus, scientists around the world have been working in collaboration to understand COVID-19.

FIGURE 4.44 Scientist wearing protective clothing while studying samples of COVID-19

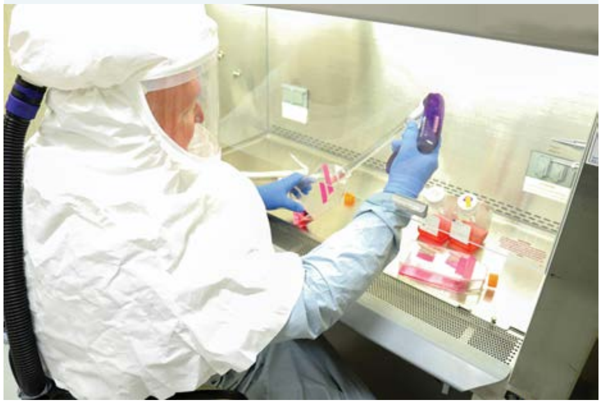


FIGURE 4.45 There are many ways to help stop the spread of contagious diseases.

on Resources

Weblink COVID-19 data

assess**on** Additional automatically marked question sets

4.6 Exercise

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To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Define the term *plague* and give one example.
2. State two differences between an epidemic and a pandemic. Give one example for each of them.
3. Suggest why bubonic plague is often referred to as the Black Death.
4. Suggest why the last recorded epidemic of bubonic plague was around 1670.
5. Provide three examples of new infectious diseases that have been identified over the last few decades.

Apply and analyse

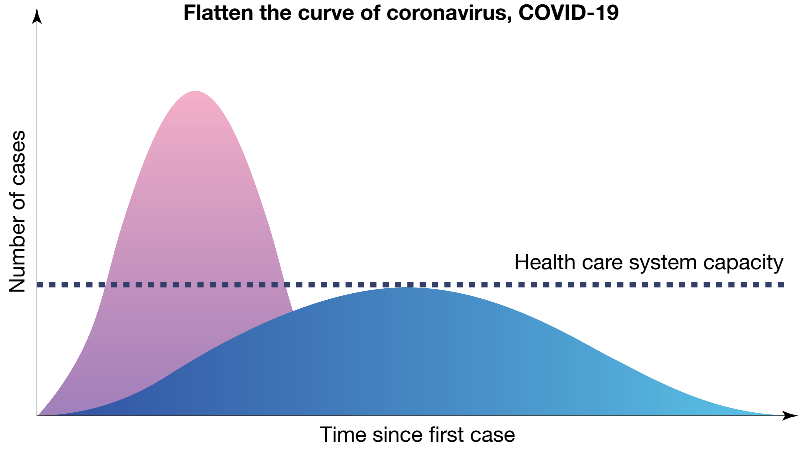
6. Construct a flow chart to show the relationship between the bubonic plague pathogen, fleas and rats.
7. Names of human diseases can change over time for various reasons. Hendra virus was originally called equine morbillivirus, but after further investigation was found not to be a morbillivirus. It was re-named after the Brisbane suburb where the first outbreak occurred. The 1918 'Spanish flu' did not originate from Spain. The swine flu outbreak had a significant impact on the meat and pork trade and the virus is now referred to as influenza A H1N1.

   In 2015 the WHO identified a best practice for naming new human diseases. Diseases are no longer named after geographical location, animal, individuals or groups of people. Explain why do you think this change was made?
8. Explain the relationship between international travel and pandemics.

9. Explain why you think COVID-19 spread so rapidly around the world?
10. Suggest three actions that can help control the spread of a virus.

Evaluate and create

11. SIS The graph shows the relationship between the number of cases of COVID-19 and the time since the first case was identified.



   a. Describe the shape of the two curves with reference to health care system capacity.
   b. Explain why it is important to 'flatten the curve' of infections.
12. Suggest how COVID-19 is different from SARS.

Fully worked solutions and sample responses are available in your digital formats.

4.7 Putting up defences

LEARNING INTENTION

At the end of this subtopic you will be able to describe how the body systems work in a coordinated way to fight pathogens through three lines of defence.

4.7.1 Antigens — You don't belong here!

Pathogens possess specific chemicals that are recognised as being non-self or foreign to your body. These non-self chemicals, referred to as **antigens**, trigger your immune response.

antigen a substance that triggers an immune response

4.7.2 Lines of defence

Pathogens can cause disease, preventing or stopping your body from working well. A healthy body helps you to defend yourself against infectious disease by setting up natural barriers, or lines of defence. The first and second lines of defence are described as being non-specific. They fight the same way for all infections, regardless of whether they have encountered them before. The third line of defence is specific. It fights differently for different types of invaders and may react differently if it has been exposed to them before.

The first line of defence

Your body's first line of defence is designed to prevent the entry of invading pathogens.

These defences (see figure 4.46) can be:

- physical barriers such as skin, coughing, sneezing, cilia and nasal hairs
- chemical barriers — body fluids such as saliva, tears, stomach acid and acidic vaginal mucus.

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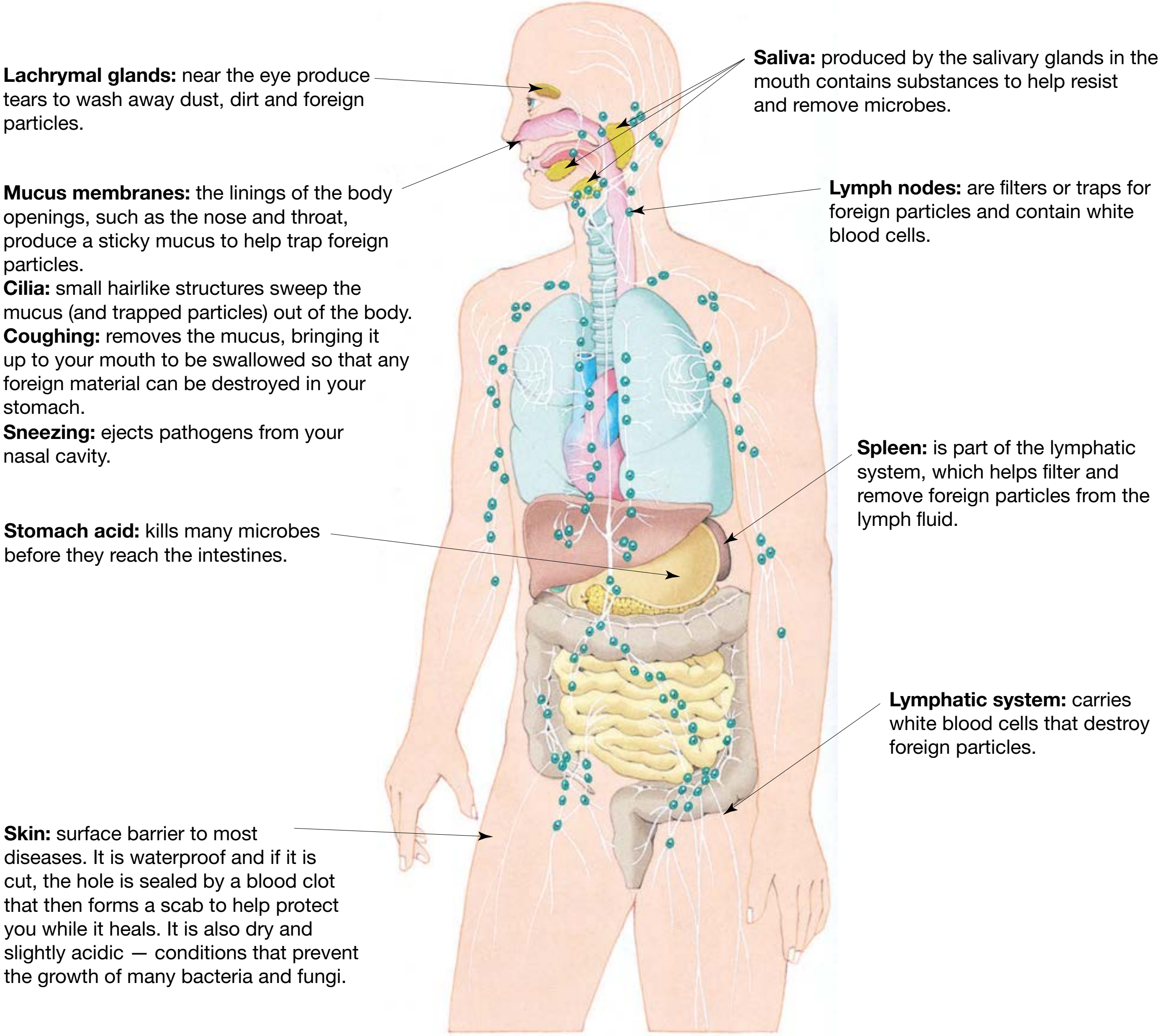
FIGURE 4.46 The body's first line of defence against disease

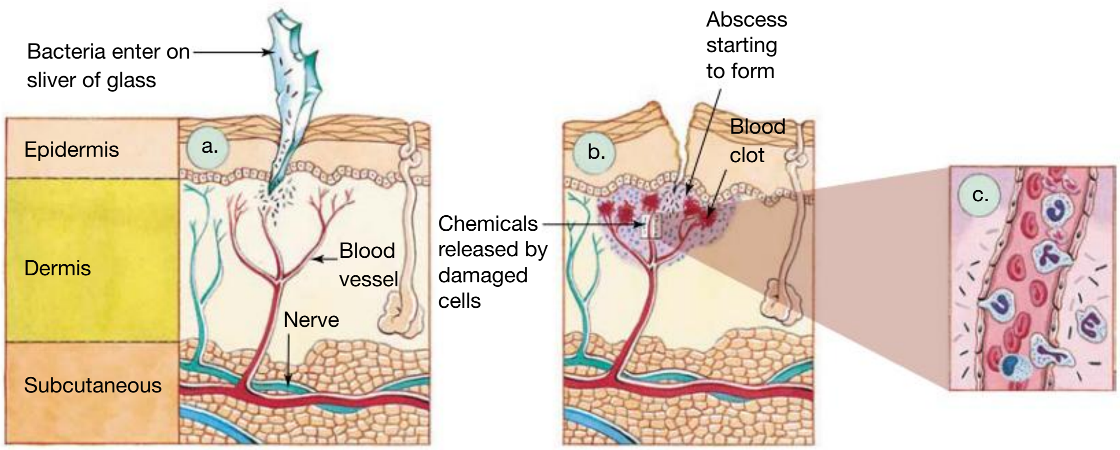


The second line of defence

If pathogens manage to get through your first line of defence, the second line of defence comes into play (see figure 4.47). If you have had a cut that became infected you may have noticed that the area became red, warm and swollen (inflamed). The redness, caused by the increased blood flow to the area, and **inflammation** are signs that your second line of defence has been triggered.

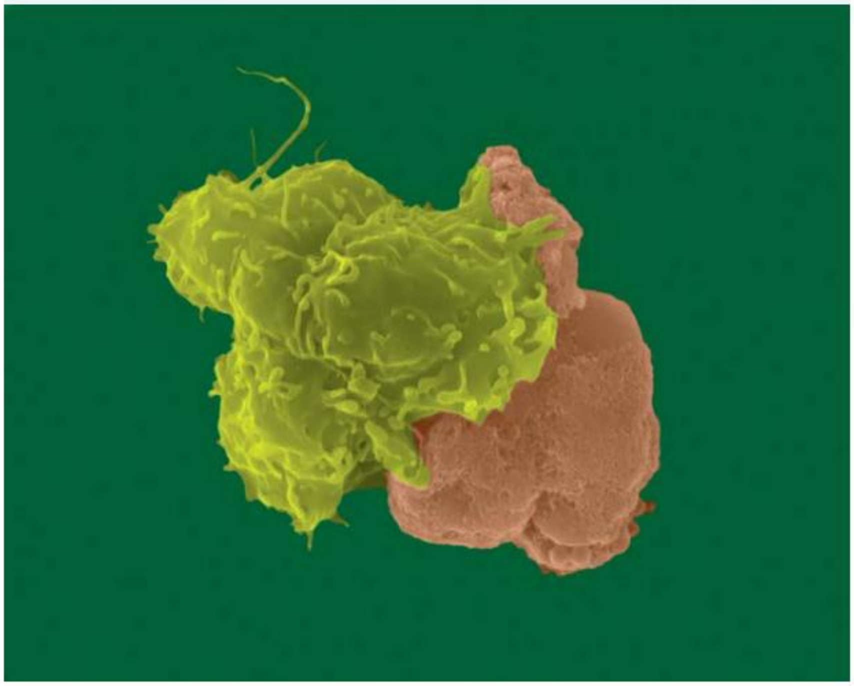
inflammation a reaction of the body to an infection, commonly characterised by heat, redness, swelling and pain

FIGURE 4.47 If a pathogen has breached your first line of defence, your skin **a.** your second line of defence, **b.** and **c.** is activated.



Special types of white blood cells, phagocytes, that engulf and destroy pathogens and other foreign material move to the site of the infection. This action of engulfing and destroying materials is called phagocytosis (see figure 4.48).

FIGURE 4.48 Phagocytes (such as some types of white blood cells) engulf and destroy materials. This action is called phagocytosis.



The third line of defence

Have you ever felt swollen glands in your neck when you had an infection? These glands are part of a network of fine tubes running throughout your body called your **lymphatic system**. Your lymphatic system contains lymph vessels, lymph nodes, lymph and white blood cells. Some of these white blood cells are **lymphocytes**.

Lymphocytes are involved in your specific immune response.

When triggered by infection:

- your **B lymphocytes** divide into **plasma cells**
- these plasma cells produce chemicals called antibodies that are specific to the invader's antigens. These antibodies assist in the destruction of the invading pathogen
- your **T lymphocytes** (or T cells) fight at a cellular level and are one of the main components of the adaptive immune system (see figure 4.49). These cells not only attack foreign invading cells, but may also attack your own cells that have been invaded. By destroying these infected cells, they also destroy the cause of infection and reduce the chance that it will be spread to other cells. There are four main types of T cells, which include T helper cells and Natural Killer T cells. Once T cells are activated, they secrete cytokines to directly attack infected or cancerous cells, and stimulate the growth of more T cells.

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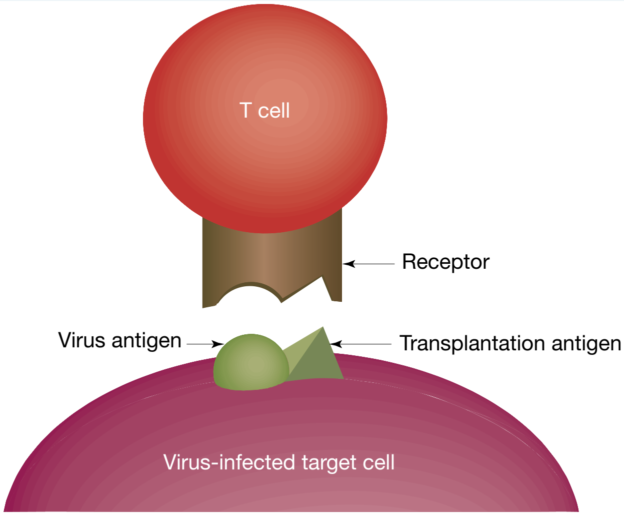
FIGURE 4.49 A killer T lymphocyte (T cell) must identify both the virus antigen and the cells of the organism it is trying to protect. It makes a matched fit at the place where the antigen is attached to the host.



The actions of lymphocytes can assist phagocytes in their duties. For example, some T lymphocytes produce substances that can attract or activate phagocytes. Antibodies (produced by B lymphocytes) can bind to antigens, causing pathogens to clump together. This clumping makes it easier for the phagocytes to engulf them.

Your immune system can be so effective that you can be infected with a pathogen but not develop any symptoms. Lymphocytes can form **memory cells**, so that next time you encounter the same type of invader your immune response can be faster and stronger. Sometimes it is so fast and strong that, even though you may be infected with the pathogen, you may not show any symptoms of the disease that it could cause.

lymphatic system the body system containing the lymph vessels, lymph nodes, lymph and white blood cells that is involved in draining fluid from the tissues and helping defend the body against invasion by disease-causing agents

lymphocyte small, mononuclear white blood cells present in large numbers in lymphoid tissues and circulating in blood and lymph

B lymphocyte part of the third line of defence, these lymphocytes may be triggered by antigens to differentiate into plasma cells that produce and release specific antibodies against the antigen; also known as B cells

plasma cell *see* B lymphocyte

T lymphocyte part of the third line of defence, these lymphocytes fight the pathogens at a cellular level. Some T lymphocytes may also attack damaged, infected or cancerous cells.

memory cells cells that may be formed from lymphocytes after infection with a pathogen — they 'remember' each specific pathogen encountered and are able to mount a strong and rapid response if that pathogen is detected again

4.7.3 Systems working together

Defence against disease is another example of how your systems work together. Your respiratory system's lining of mucus and ciliated tubes and your digestive system's enzymes and stomach acids help your fight against invaders. White blood cells produced in your bone marrow include those that will become phagocytes and lymphocytes. These defending cells will be circulated throughout your body in your circulatory system and lymphatic system to areas of infection, where they perform their task of destroying invaders. The remnants of these invaders are then excreted from your body via your excretory system.

EXTENSION: HIV attack on T cells

A type of T lymphocyte called the *helper T lymphocyte* (helper T cell) can be infected by the Human Immunodeficiency Virus (HIV). This is the virus that causes AIDS (Acquired Immune Deficiency Syndrome). HIV destroys the helper T cells, and in doing so gradually damages the immune system of the infected person; this is why people with AIDS often die from diseases that a healthy immune system could normally defend itself from. HIV can be transmitted through body fluids such as blood, semen, vaginal fluid and breast milk. While there is currently no known cure, treatment for HIV is called antiretroviral therapy. This therapy aims to reduce the person's viral load to a level where HIV in the blood is too low to be detected by a viral load test. The viral load is reduced by HIV medicines, which prevent HIV from multiplying. By reducing the amount of HIV in the body, the immune system has a chance to recover and produce more T lymphocyte cells.

FIGURE 4.50 HIV (orange) attacking a T lymphocyte

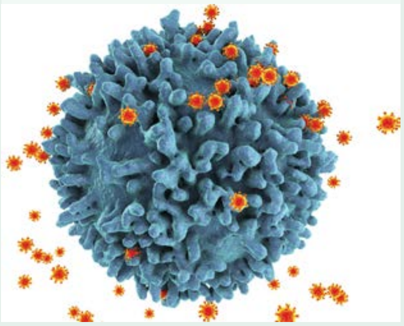
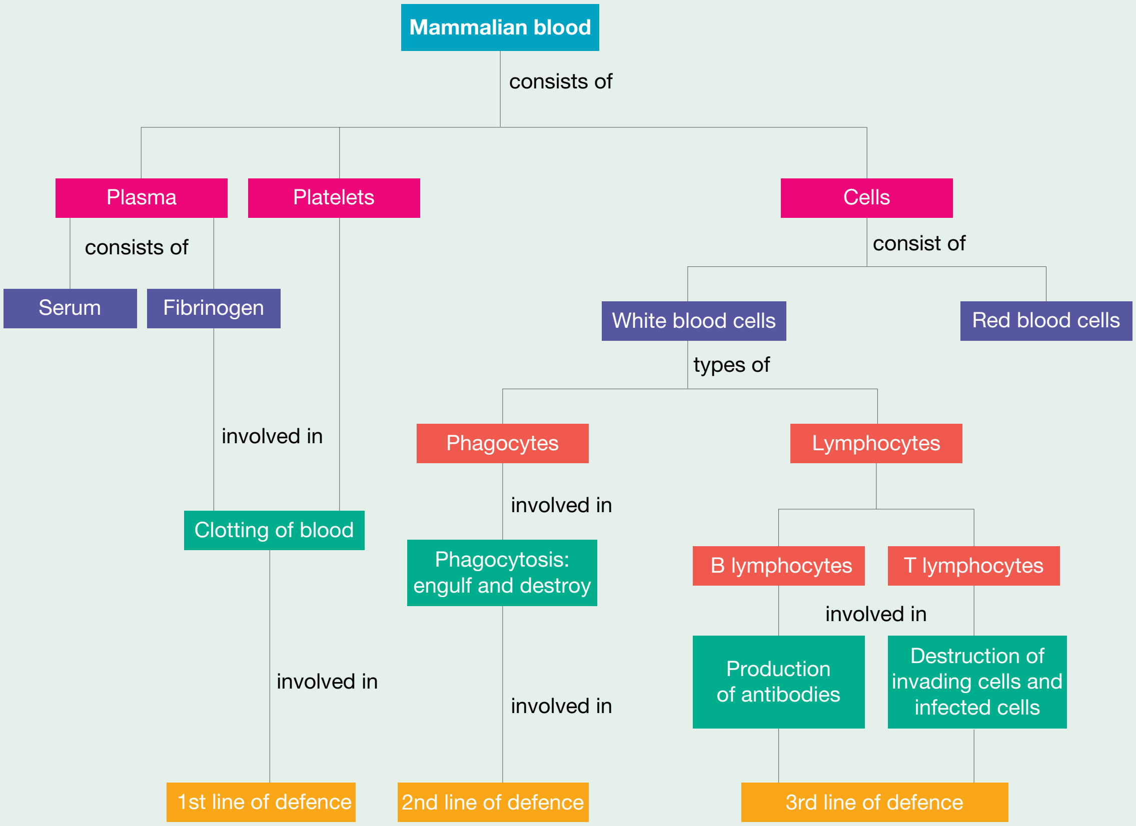


FIGURE 4.51 Your blood is involved in your body's defence against disease.



on Resources

Video eLesson Understanding HIV (eles-0125)

assesson Additional automatically marked question sets

4.7 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1 Explain how cilia, mucus, coughing and stomach acids can work together to help defend you against pathogens.

2 State three lines of defence that protects your body against pathogens and describe one key difference between each of them.

3 a. Explain why many species of bacteria and fungi find it difficult to grow on skin.
  b. Describe some of the microorganisms that typically reside on human skin (normal skin microbiota)? Explain why they are of benefit to us and how they contribute to our first line of defence against pathogens?

4 Provide two examples of (a) physical barriers and (b) chemical barriers involved in the first line of defence.

Apply and analyse

5. Use labelled flowcharts to show the relationship between:
   a. pathogens, phagocytes and phagocytosis
   b. antigens, pathogens, antibodies, lymphocytes, and phagocytes.
6. Suggest three ways in which foreign particles might be able to enter your body.
7. Explain how you can be infected with a pathogen but not show any symptoms.
8. Explain how:
   a. T cells protect us from disease
   b. T cells recognise that a body cell has been infected by a virus.
9. Outline how your blood is involved in each line of defence against disease.

Evaluate and create

10. Use Venn diagrams to compare the following:
    a. First and second lines of defence
    b. Second and third lines of defence
    c. Physical and chemical barriers in the first line of defence
11. Use Venn diagrams to compare the following:
    a. Inflammation and phagocytosis
    b. Phagocytes and lymphocytes
    c. T lymphocytes and B lymphocytes

Fully worked solutions and sample responses are available in your digital formats.

4.8 Immunity and immunisation

LEARNING INTENTION

At the end of this subtopic you will be able to explain what immunity is, how it develops and how the development of vaccines have positively affected the world in the fight against smallpox, polio and HPV.

4.8.1 Immunity and immunisation

Immunity is resistance to a particular disease-causing pathogen. A person who is immune does not develop the disease.

If a person is exposed to the antigen of a particular pathogen, or non-self material, they may make specific antibodies against it. The next time they encounter that antigen, their response may be so fast and effective that they can resist infection (figure 4.52).

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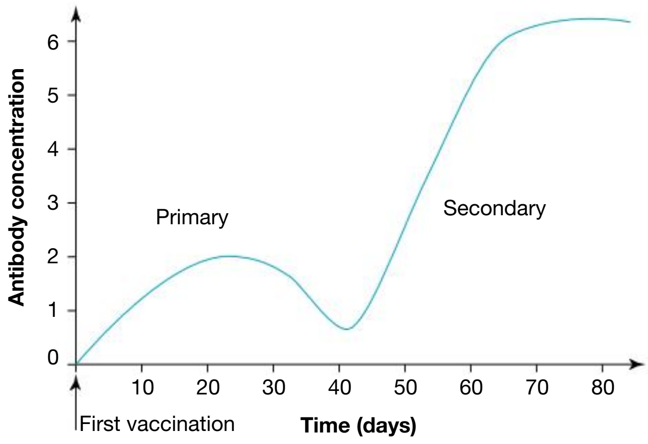
FIGURE 4.52 On the second exposure to an antigen, the immune system is able to start producing antibodies more rapidly and in greater amounts.



The development of one type of immunity involves the use of a vaccine. Vaccination or **immunisation** is the giving of the vaccine to produce a type of immunity called artificial immunity. Vaccination trains the immune response to fight against a pathogen without being exposed to the dangers of pathogen itself. Vaccination generates antibody responses against and immunological memory of the pathogen, mimicking the primary infection without being infected.

immunisation administering an antigen, such as in a vaccine, with the aim of producing enhanced immune response against the antigen in a future exposure

Tetanus vaccination

In the case of tetanus, a safe part of the tetanus toxin produced by *Clostridium tetani*, called tetanus toxoid, is used as the antigen to generate a protective immune response (generation of antibodies) against the deadly toxin. When someone who has been vaccinated against tetanus is exposed to it, these pre-existing antibodies bind rapidly to the tetanus toxin and prevent the toxin from binding to and affecting the nerves and muscles. This prevents paralysis and death. Memory cells respond quickly (within a few days) rapidly removing the bacteria and producing higher levels of antibodies against the toxin (see example in figure 4.52). An unvaccinated person has no pre-existing antibodies to bind the toxin which would kill the person in 1–2 days. The antibody response would take weeks to occur without prior vaccination (primary response).

Active and passive immunity

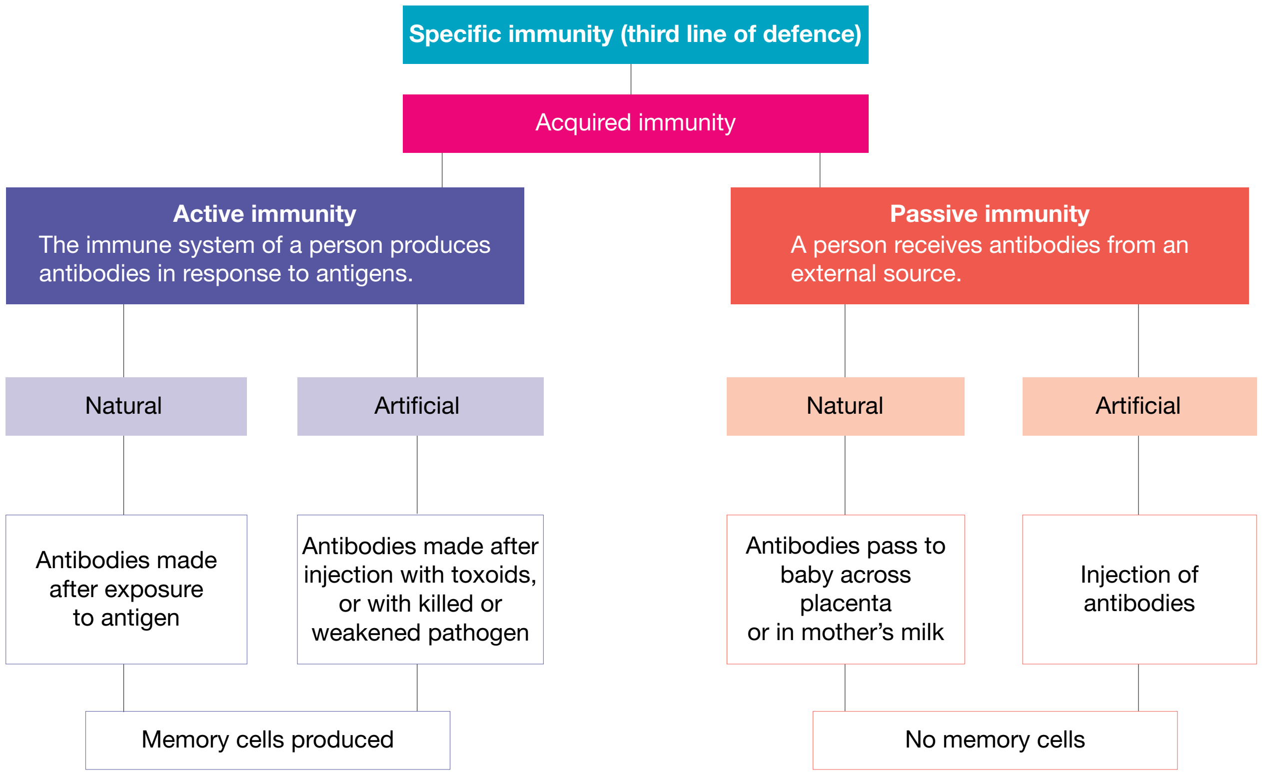
If your body makes antibodies to a specific antigen, this is described as **active immunity**. Your body has memory cells that remember the antigen and you can make more identical antibodies very quickly. You could also gain artificial (or induced) active immunity by producing antibodies after being injected with a toxoid or a killed or treated pathogen that contains the antigen.

If you receive antibodies from an outside source, this is called **passive immunity**. In this case, you don't have memory cells for this infection so, if you were exposed to it again, your body would react as it did the first time. You could get passive immunity from your mother's milk, across the placenta or through an injection of antibodies.

active immunity immunity achieved by your body making antibodies to a specific antigen

passive immunity immunity achieved by your body receiving antibodies from an outside source, such as from your mother's milk or through vaccination

FIGURE 4.53 Immunity can be active or passive, and acquired naturally or artificially.



SCIENCE AS A HUMAN ENDEAVOUR: The development of vaccines

Smallpox

Observations that, once infected, a survivor of a disease often did not catch that disease again must have been made throughout history. A long time before vaccination had been created in England, the Chinese used this observation as a basis for a process called **variolation**.

variolation deliberate infection of a person with smallpox (Variola) in a controlled manner so as to minimise the severity of the infection and also to induce immunity against further infection

In the case of smallpox, variolation involved transferring material from the lesions of those infected with smallpox to healthy individuals. The transference was achieved by inserting infected material under the skin or inhaling the infected powder. The relative success of this process in reducing mortality and morbidity rates resulted in its spread to other countries.

It was an English aristocrat and writer, Lady Mary Wortley Montagu (1689–1762), who was responsible for bringing variolation to England from Turkey around 1721. She had been scarred by smallpox herself and had also lost close relatives to it. Although variolation was used by some of the aristocracy (including the royal family), it was not until 1797 that Edward Jenner (1749–1823) refined this method. Jenner noticed that people who had contracted cowpox, a much less serious disease, did not seem to ever develop smallpox. Jenner took some pus from an infected cow and deliberately gave a person cowpox. Some time later he exposed this person to smallpox, but the person never showed signs of the illness. Jenner had successfully produced an immunity to smallpox. He called the method **vaccination**, from the Latin word for cow, *vacca*. Jenner's vaccination method was able to be used by wider populations, and occasionally its use was enforced. By 1980, because of the use of vaccination, the World Health Organization (WHO) was able to announce the elimination of smallpox from our planet.

FIGURE 4.54 Smallpox leaves the sufferer with scarred skin.

FIGURE 4.55 Lady Mary Wortley Montagu

Polio

Poliomyelitis (polio) is a disease caused by the *Picornaviridae* virus. This disease is highly infectious and consequences can include complete recovery, limb and chest muscle paralysis, or death. It is not contagious, but spreads by consuming contaminated water or food.

A vaccine for polio was developed by Jonas Salk in 1955 using a dead virus. However, this vaccine required a booster shot about every 3 years and occasionally a live virus contaminated the vaccine. One batch in 1955 infected 44 children with polio; this resulted in some fear within the population about its use. In 1956, American doctor, Albert Sabin, announced that his oral live virus polio vaccine was ready for mass testing. Public mistrust in the safety of a vaccine using a live virus resulted in Sabin using Soviet (Russian) school children in his large population tests. His tests indicated that this vaccine was not only safer, but also more effective, providing lifelong immunity — and it was cherry-flavoured and could be taken by mouth! By 1961, Sabin's oral polio vaccine was adopted as the standard in America. In 1966, Australia also introduced this oral vaccine The entire western Pacific region (including Australia) has been declared polio-free since 2000. One case was reported in 2007, in a traveller who acquired polio overseas. Given the extent of travel around the world, polio vaccination remains an important part of Australia's immunisation schedule.

vaccination administering a vaccine to stimulate the immune system of an individual to develop immunity to a disease

poliomyelitis a highly infectious disease caused by the *Picornaviridae* virus that can have consequences including complete recovery, limb and chest muscle paralysis, or death

FIGURE 4.56 Dr Albert Sabin and his vaccine against polio

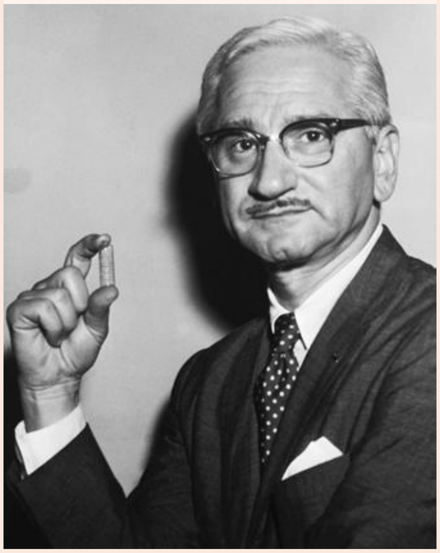


FIGURE 4.57 People suffering with polio may become paralysed.

Cervical cancer

Human papillomavirus (HPV) is the cause of greater than 90 per cent of cervical cancers. Cervical cancer was responsible for the deaths of more than 300 Australian women each year. A vaccine against the papillomavirus was developed by Professor Ian Frazer from the University of Queensland's Centre for Immunology and Cancer Research. He was recognised as Australian of the Year in 2006 for his involvement in this development. Vaccination against HPV began in 2007 for girls aged 12–13 years and has resulted in a significant decrease in the cervical cancer rate of women who have been vaccinated. This vaccine may assist in the prevention and eventual eradication of cervical cancer, which currently affects more than half a million women worldwide each year.

In years gone by, women had a Pap test every 2 years, which was used to detect pre-cancerous and cancerous cells. In Australia, this has been replaced by the Cervical Screening Test in women from the ages of 25–75. This test detects the presence of HPV before the cells have become cancerous. Predictive modelling indicates that if screening and vaccination rates remain at current levels, cervical cancer could be eliminated as a public health issue in Australia by 2035.

FIGURE 4.58 Ian Frazer developed the HPV vaccine, which may help eradicate cervical cancer.

4.8.2 Vaccination in Australia

Vaccinations have been developed by scientists against many diseases and are available to the majority of Australians. This has meant that many children have not had to experience some of the horrors experienced by previous generations. Community health programs ensure that children are vaccinated to protect them against infectious diseases such as tetanus, rubella, mumps, diphtheria, poliomyelitis and whooping cough. Many of these diseases have now been controlled so are rarely seen in Australia.

Alarmingly, there is an increasingly low child immunisation rate in some areas in Australia. This has resulted in the government taking steps to boost the numbers of children immunised.

TABLE 4.2 Vaccine program schedule

National Immunisation Program Schedule 1 April 2019

Australian Government Department of Health | National Immunisation Program — A joint Australian, State and Territory Government Initiative

	Childhood							Adolescent		Adult				
Vaccine Brand Name	Birth	2 mths (from 6 weeks)	4 mths	6 mths	12 mths	18 mths	4 yrs	12–<13 yrs (school programs)	14–<16 yrs (school programs)	Pregnant women	Indigenous* >15 yrs	Indigenous* >50 yrs	>65 yrs	70 yrs
H-B-Vax® II Paediatric or **Engerix® B – Paediatric** (Hep B)	✔ (within 7 days)													
Infanrix® hexa (DTPa, Hep B, Polio, Hib)		✔	✔	✔										
Prevenar 13® (Pneumococcal)		✔	✔	✔ Medically at-risk and Indigenous* (QLD, NT, WA, SA)	✔									
Rotarix® (Rotavirus)		✔	✔											
Nimenrix® (MenACWY)					✔				✔					
ActHIB® (Hib)						✔								
MMRII® or **Priorix®** (MMR)					✔									
Priorix-Tetra® or **ProQuad®** (MMRV)						✔								
Infanrix® or **Tripacel®** (DTPa)						✔								
Infanrix® IPV or **Quadracel®** (DTPa, Polio)							✔							
Vaqta® Paediatric (HepA)					✔ Indigenous* (QLD, NT, WA, SA)	✔ Indigenous* (QLD, NT, WA, SA)								
Gardasil®9 (HPV)								✔ 2 doses (6 months apart)						
Boostrix® (dTpa)								✔						
Boostrix® or **Adacel®** (dTpa)										✔				
Pneumovax23® (Pneumococcal)							✔ Medically at-risk				✔ Medically at-risk	✔	✔	
Zostavax® (Herpes zoster)														✔**

Annual influenza vaccination	– 6 months and over with certain medical risk factors – All Aboriginal and Torres Strait Islander people 6 months and over – 65 years and over – Pregnant women

*The term Indigenous is inclusive of Aboriginal and Torres Strait Islander people
** Until 31 October 2021, a catch-up dose is also available for 71 to 79 year olds

All people aged less than 20 years are eligible for free catch up vaccines. | Adult refugees and humanitarian entrants are eligible for free catch up vaccines. | Additional vaccines might be funded by some States and Territories

For more information **visit health.gov.au/immunisation**

4.8.3 Travel bugs

If you are planning an overseas trip, it's recommended that you research the conditions in your holiday destination carefully. Otherwise you may bring back more than you expect!

Although many travellers are aware that immunisations to travel to certain countries are recommended, the most common illness suffered by overseas travellers is diarrhoea. While this may cause a little discomfort in the short term, it may be lethal if it continues for a long time. It is responsible for the deaths of almost five million children in tropical regions each year. There are no vaccines to protect you against it, but you can reduce your risk of getting diarrhoea by following a few simple precautions. These include avoiding uncooked foods that may have been washed with contaminated water or handled unhygienically. Only bottled or boiled water may be safe to drink.

Travel vaccinations

Vaccines are currently available for some strains of hepatitis, typhoid, yellow fever, Japanese encephalitis, cholera, influenza, rabies and bacterial meningitis.

If you are travelling to a region where malaria is a problem, you are advised to begin a course of antimalarial tablets before leaving. This preventative action should be continued for at least a month after your return. Some countries require proof of a vaccination against yellow fever before you are allowed to enter the country.

FIGURE 4.59 Proof of a vaccination against yellow fever

EXTENSION: No more needles? Vaccine delivery via patch

Since 1853, the syringe has been the main delivery system for vaccines. Professor Mark Kendall and his team of researchers at the University of Queensland have developed a game changer for vaccine delivery — a painless tiny skin patch that doesn't require trained doctors and nurses to deliver, or refrigeration of the vaccine. Find out more about the Vaxxas nanopatch. Consider the following points:

- How does the nanopatch deliver the vaccine antigens? Which cells are targeted in the person being vaccinated?
- How will the nanopatch benefit African countries? Compare and contrast with the benefits for Australia.
- What is the first vaccine being trialled using this new technology in conjunction with the World Health Organization (WHO)?

on Resources

Video eLesson Immunisation in Australia (eles-0126)

eWorkbooks Immunity (ewbk-5193)
Vaccination (ewbk-5195)

assess on Additional automatically marked question sets

4.8 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Describe a way in which each of the following people contributed to the fight against disease.
   a. Lady Montagu b. Edward Jenner c. Jonas Salk d. Albert Sabin
2. Distinguish between the following:
   a. Immunity and immunisation
   b. Antigen and antibody
   c. Active immunity and passive immunity
   d. Natural passive immunity and artificial passive immunity
   e. Natural active immunity and artificial active immunity

Apply and analyse

3. SIS Whooping cough, caused by *Bordetella pertussis*, is a very serious infection of the respiratory system. It can cause violent coughing fits. The cough has a distinctive whooping sound, which led to the disease name. Whooping cough is most harmful for young babies and can be deadly.
   a. Look at the vaccination schedule (table 4.2). Pertussis (whooping cough) is vaccinated against using the DTP (diphtheria, tetanus and pertussis) vaccine. When are children vaccinated against whooping cough?
   b. Explain how unborn babies and newborn babies can be protected against whooping cough before they are old enough for their first vaccination.

c. Should people visiting babies in hospitals and homes, including grandparents, be required to be vaccinated? Yes or No. Give reasons for your answer.
d. Does the vaccine provide life-long protection? If not, how often should people be given a booster shot of the vaccine to remain protected?

4. 'No Jab, No Play' is the name of legislation that requires all children to be fully vaccinated, unless they have a medical exemption, to be enrolled in childcare or kindergarten in Victoria. Who else is vulnerable to harm and potential death from this disease in our community?
5. a. Describe herd immunity.
   b. Explain why the World Health Organization states that 95% of the population needs to be vaccinated against a pathogen to maintain herd immunity.
   c. Predict what happens when vaccination rates drop to 80% of the population.

Evaluate and create

6. **SIS** The following table shows statistics of the number of people infected with vaccine-preventable diseases in Victoria from January 2019 to January 2020.

TABLE Infections of preventable diseases in Victoria, 2019

Vaccine Preventable Diseases	128 (current)
Diphtheria	0
Haemophilus influenzae type B infection	0
Influenza	63
Measles	1
Meningococcal infection	0
Mumps	0
Pertussis	54
Invasive pneumococcal disease (IPD)	10
Rotavirus infection	0
Rubella	0
Tetanus	0
Varicella zoster infection (chickenpox)	0
Varicella zoster infection (shingles)	0
Varicella zoster infection (unspecified)	0

   a. Use the table to identify how many whooping cough infections there were from January 2019 to January 2020. Suggest why there were so many whooping cough infections when cases of other vaccine-preventable diseases were not occurring in the same 12-month period.
   b. Do you think we will ever be able to eradicate whooping cough from the planet, as was done with smallpox?
7. **SIS**
   a. Draw a flow chart showing the effect of *Clostridium tetani* infection on the human body systems. Include the time it would take for a person to die from tetanus if unvaccinated.
   b. Explain why a person who has been vaccinated against tetanus does not die when they are infected with *Clostridium tetani*. Refer to figure 4.52.
   c. Compare the response in part b to an unvaccinated person.

Fully worked solutions and sample responses are available in your digital formats.

4.9 Our noble Nobels

LEARNING INTENTION

At the end of this subtopic you will be able to provide examples of some of the contributions that our Australian Nobel Prize winners have made to scientific knowledge and understanding.

4.9.1 Australian Nobel Prize winners

Australian scientists have made significant contributions to disease control and to the quality of life that we enjoy today. Sir Howard Florey, Sir Frank Macfarlane Burnet and Professor Peter Doherty each won a Nobel Prize in Medicine.

One hundred years ago, many children died from both infectious diseases and bacterial infections. A small scratch was sometimes enough to allow deadly bacteria to enter the body and cause swelling, the formation of pus and severe pain. Children born today can avoid the harsh consequences of most bacterial infections.

SCIENCE AS A HUMAN ENDEAVOUR: Howard Florey — Marvellous mould

Howard Florey was born in Adelaide in South Australia in 1898. He was a keen student who loved sport and chemistry. He studied medicine at the University of Adelaide where he won a Rhodes scholarship to Oxford University, England. While in England he led the team who finally extracted **penicillin** in 1940. In 1945 he shared his Nobel Prize with Alexander Fleming and Ernst Chain. In speaking of his discovery, he modestly stated, 'All we did was to do some experiments and have the luck to hit on a substance with astonishing properties.'

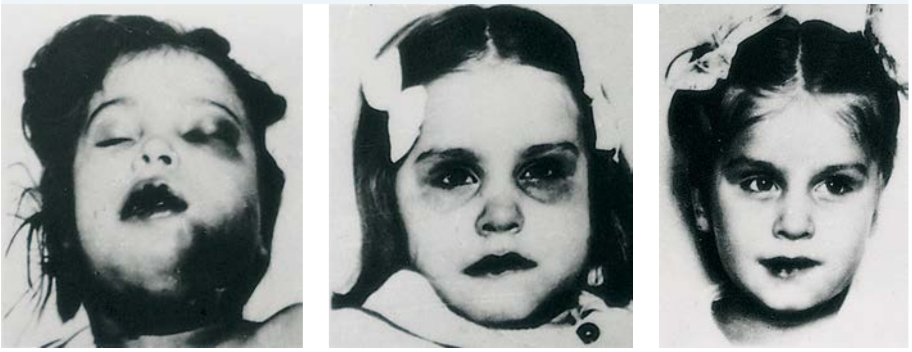
Penicillin was so successful in saving lives that population control became an issue for medical researchers. Florey later worked on contraception research. In honour of his contribution to medicine, he was knighted in 1944. His likeness appeared on an Australian $50 banknote and a suburb of Canberra was named after him.

FIGURE 4.60 Howard Florey

4.9.2 The miracle of penicillin

Penicillin is an antibiotic and is a chemical made by the mould (fungus) *Penicillium*. If you leave oranges for too long in the fruit bowl, you will sometimes find them growing a greenish mould. This is *Penicillium*. Antibiotics destroy bacteria, and they are widely used to treat diseases caused by bacteria.

FIGURE 4.61 These photographs from 1942 show how serious a bacterial infection can be. After being treated with penicillin, the patient's condition improved and she recovered fully.



penicillin a powerful antibiotic substance found in moulds of the genus *Penicillium* that kills many disease-causing bacteria

In the human bloodstream, penicillin works by stopping bacteria from forming cell walls as they try to divide. Natural penicillin must be given by injection as otherwise it is destroyed by stomach acid. Some people are allergic to penicillin, but luckily there are now several different antibiotics to choose from. There are few people in the community who have not taken antibiotics at some time in their lives.

While pencillin has saved millions of lives, there are now strains of bacteria that are becoming resistant to penicillin. These include *Staphylococcus aureus* ('golden staph' or MRSA) and *Neisseria gonorrhoeae* (the cause of gonorrhoea). This resistance develops due to mutations (or changes) to the bacteria that result in the bacteria being able to affect the penicillin before it has a chance to work. This resistance is thought to be due to overuse of antibiotics, which allows the bacteria to mutate. These mutations in the bacteria affects penicillin in different ways:

- the bacteria can break down the antibiotic through degradation by enzymes
- changes to the bacterial proteins that are the targets for the antibiotic
- changes in membrane permeability of the bacteria to antibiotics.

SCIENCE AS A HUMAN ENDEAVOUR: Frank Macfarlane Burnet — The father of immunology

Frank Macfarlane Burnet, known as 'Mac', was born in Traralgon, Victoria in 1899 and died in 1985. As a boy, he loved science and spent hours exploring the bush near his home searching for beetles. Charles Darwin was his hero. After graduating from the University of Melbourne as a medical researcher, he started work at the Walter and Eliza Hall Institute (WEHI) in Melbourne. He then worked in England for many years, returning to Australia in 1944 to become director of the WEHI. He was knighted in 1951 and received his Nobel Prize in 1960. In 1961 he was named Australian of the Year, and 4 years later he was elected President of the Australian Academy of Science.

FIGURE 4.62 Mac demonstrates his method of growing viruses by injecting them into eggs to a class of American postgraduate students.

Immunology, the science that deals with protection from diseases, was Mac's specialty and he spent most of his career studying viruses. His doctorate thesis was on the **phage**, a type of virus that infects and kills bacteria. Scientists of the time thought there was only one species of phage. Mac showed that there are, in fact, several species.

In 1928, there was public hysteria against vaccination when 12 children died after receiving their diphtheria injections. Mac was part of a team that investigated this tragedy. His experiments showed that contamination of the vaccine caused the deaths, rather than the vaccine itself. This no doubt saved many further lives as people regained their confidence in vaccination.

immunology the branch of science that deals with immunity from disease

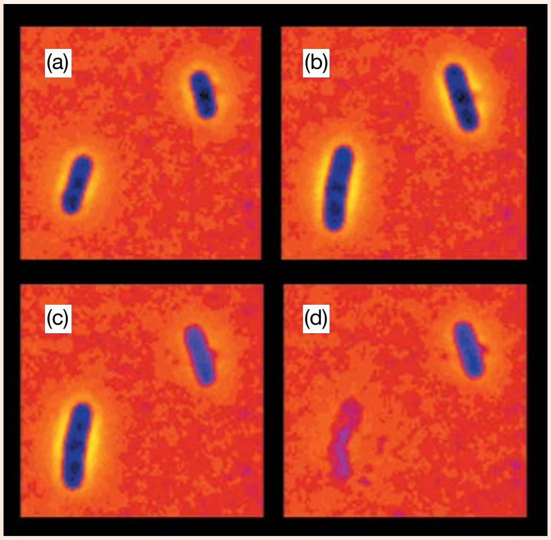
phage a type of virus that infects and kills bacteria

Influenza strains

While in England, Mac worked on the human influenza (flu) virus and developed a successful method of growing high concentrations of the virus using fertilised chickens' eggs. This work led to the development of an influenza vaccine. Mac determined that there were several different strains of influenza. This meant a new vaccine had to be developed each year once the particular strain of influenza had been identified. His work laid the foundation for the discovery by Dr Peter Coleman from CSIRO that all influenza viruses had a common part. Researchers then focused on ways to attack this common part and were able to produce drugs that can kill all strains of influenza virus. Now, people in high-risk categories are encouraged to be vaccinated each autumn to avoid contracting the disease.

Mac was so dedicated to his work that he was willing to risk his life to show others what he knew. In the early 1950s, CSIRO released the myxomatosis virus so it would infect and reduce the rabbit population in Australia. At the same time, there was an outbreak of encephalitis that made hundreds of people sick. The public started to blame myxomatosis. Mac knew how the myxoma virus worked and that it could not affect humans. He set up an experiment where he and two colleagues, Professor Frank Fenner and Dr Ian Clunies Ross, injected themselves with live myxoma virus. When it was shown that their health was not affected, the panic died down.

FIGURE 4.63 In these photographs, bacteria were grown in penicillin for 30 minutes. The bacteria grow longer as shown at (b), but eventually rupture (d), unable to divide due to the influence of the penicillin.



4.9.3 The immune system and organ transplants

Mac's work inspired other scientists, contributing to our ability to perform transplants. Mac believed that the body learns about immunity at an early age. He suggested that if you could put cells from another body into a foetus at the right time, the foetus would learn not to reject such cells later in life.

In 1951, Dr Peter Medawar and his team of scientists used this idea when they injected donor tissue from a mouse into the embryo of another mouse. When the mouse was born, the team grafted skin from the donor mouse onto the newborn mouse. No rejection occurred. Now scientists know that they must match the genes carefully when they are looking for possible transplant organs. They use a close genetic match between recipients and donor organs, together with drugs that deaden the immune system, to perform successful transplantations. Today organs including heart, lung, kidney, cornea, bone marrow, skin and pancreas may be transplanted, extending the lives of many people. Immunology is still an important area of scientific research.

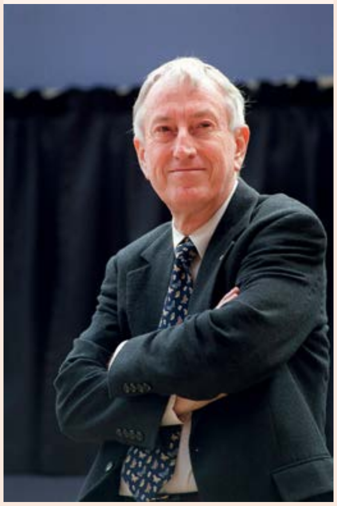
SCIENCE AS A HUMAN ENDEAVOUR: Peter Doherty — Understanding the immune system

Professor Peter Doherty was born in Brisbane in 1940. He received a veterinary science degree from the University of Queensland and a graduate medical degree from the University of Edinburgh. He shared his Nobel Prize in 1996 with Rolf Zinkernagel when they described the way the **immune system** recognises virus-infected cells. In 1997 Peter Doherty was named Australian of the Year. Doherty and Zinkernagel worked at the John Curtin School of Medical Research in Canberra from 1973 to 1975.

immune system a network of interacting body systems that protects against disease by identifying and destroying pathogens and infected, malignant or broken-down cells

The immune system uses special white blood cells called T lymphocytes, or T cells, to protect an organism from infection by eliminating invading microbes. T cells have to be smart enough to avoid damaging their own organism. They need a recognition system so that they can identify the parts they must destroy and those they must protect. The body also needs to know when to activate them.

FIGURE 4.64 Laureate Professor Peter Doherty



Doherty and Zinkernagel studied mice to learn how their immune systems (particularly their T cells) protect them against the virus that causes meningitis. They discovered that mice can make killer T cells that protect them. However, when these T cells were placed in a test tube with infected cells from another mouse, they did not work. Doherty and Zinkernagel developed a model to explain why this happened. They said that each T cell carries a marker that allows it to recognise the cell of the organism it is protecting, as well as the antigen of the invading microbe. At the spot where the antigen attaches itself to the host, the T cell can make a matched fit and destroy the antigen. It works like two interlocking pieces of a jigsaw puzzle.

When your body is exposed to a microbe, it develops T cells that give it immunity. If there are enough of the right type of T cells, these can eliminate the microbes faster than they can reproduce and you remain well. Your body keeps some of these T cells as immunity against future attacks from the same microbe.

This work has had a major impact on our understanding of organ transplantation and vaccines. Scientists now realise they must try to match both tissue and immune system types for a successful transplantation. Laureate Professor Peter Doherty is now the patron and namesake of the Doherty Institute for Infection and Immunity, which is a research facility between the University of Melbourne and the Royal Melbourne Hospital. He is still active in Science, and has also written a number of popular Science books, including *The Beginners Guide to Winning the Nobel Prize*.

4.9.4 From Pasteur to penicillin

Understanding and finding cures for infectious diseases has been a long process involving the efforts of many scientists around the world. Some of the key researchers in the discovery and development of penicillin, and their ideas and breakthroughs, are listed in tables 4.3 and 4.4. If it were not for their contributions, we may not have the antibiotic medicines that we take for granted today.

TABLE 4.3 Australian Nobel Prize-winning scientists

Year of Nobel prize	Scientist	Contribution to our understanding of disease
1945	Howard Florey (1898–1968)	Isolation and manufacture of penicillin and discovery of its curative effect in various infectious diseases
1960	Frank Macfarlane Burnet (1899–1985)	Discovery of acquired immunological tolerance
1996	Peter Doherty (1940–)	Discoveries about the specificity of the cell-mediated immune defence
2005	Barry Marshall (1951–) and Robin Warren (1937–)	Discovery of the involvement of the *Helicobacter pylori* bacterium in stomach ulcers and gastritis

TABLE 4.4 Other notable Nobel Prize–winning scientists

Scientist	Field	Contribution to our understanding of disease
Louis Pasteur (1822–1895)	French chemist	Discovered that infectious diseases are spread by bacteria. Observed that mould stopped the spread of anthrax
Joseph Lister (1827–1912)	British surgeon	Noted that samples of urine contaminated with mould prevented bacterial growth
Alexander Fleming (1881–1955)	Scottish bacteriologist	In 1928, while studying the influenza virus, Fleming went on holiday and left several discarded Petri dishes on his bench. He had been using them to grow bacteria in nutrient jelly. When he returned, he noticed that where some of the mould had fallen, the bacteria had been killed. He called this substance penicillin but was unable to extract it and did not pursue it further.

on Resources

assesson Additional automatically marked question sets

4.9 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Who discovered that infectious disease was spread by bacteria?
2. Sir Howard Florey, Sir Frank Macfarlane Burnet and Professor Peter Doherty are Australians who have received a Nobel Prize for their contributions to medical research.
   a. Which Nobel Prize did each win and in what year?
   b. In which area of science did each one specialise?
3. Are there any strains of bacteria that are resistant to penicillin?

Apply and analyse

4. Explain what would have happened to you if you had a bacterial infection in the time before penicillin was discovered?
5. Explain how does antibiotic resistance develop?

Evaluate and create

6. SIS Howard Florey infected eight mice with streptococcus. Four of the mice that were given a penicillin injection survived the infection and those that did not receive penicillin died from the infection.
   a. Explain why the mice given the penicillin injection survived the infection. Explain how penicillin works.
   Following the success of penicillin in treating infection in mice, Florey and his team of scientists produced cultures of *Penicillium notatum* as a source of penicillin in the 'fungus juice' to try to slow or counteract bacterial infections in humans. In 1940, Oxford Police Constable, Albert Alexander, was hospitalised following infection with streptococcus and staphylococcus, resulting from a rose bush's scratch to his face. Howard Florey's wife, Ethel, a pharmacologist, brought Albert's plight to his attention, as other treatments were failing and Albert's face was covered in abscesses. Albert lost his eye to the infection. Within 24 hours of injection with penicillin, Albert was showing signs of recovery. After 5 days of treatment the penicillin ran out. They had even been extracting penicillin from Albert's urine to prolong his treatment.
   b. Suggest why the penicillin treatment was successful in mice but was unable to save Albert.
   c. Suggest reasons why the young girl pictured in figure 4.61 with a serious infection in 1942 fully recovered after treatment with penicillin.
   d. Investigate improvements in the production of penicillin that have led to the drop in the death rate from infections during World War II, ending in 1945, and beyond.

Fully worked solutions and sample responses are available in your digital formats.

4.10 Thinking tools — Cycle maps and relations diagrams

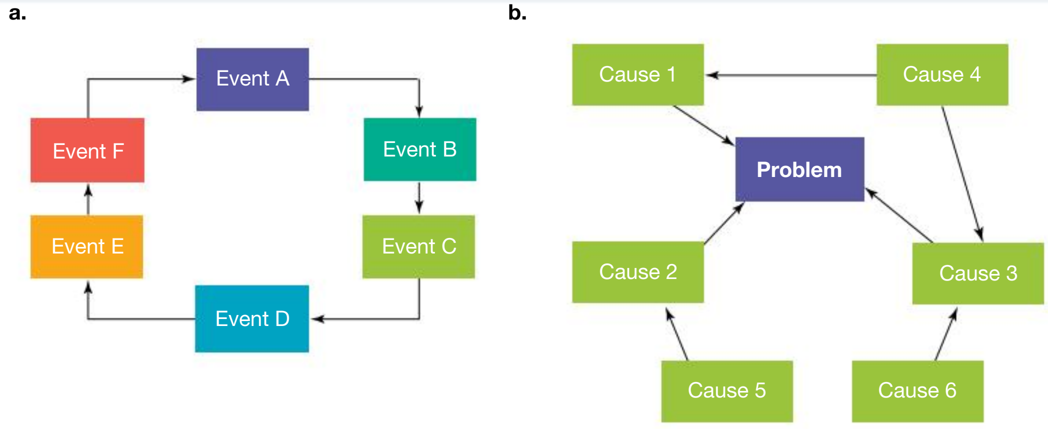
4.10.1 Tell me

What are cycle maps and relations diagrams?

A cycle map is a diagram that is useful for showing a circular or repeating event or process. It helps you arrange a complex sequence of events that contains a number of steps, which each depend upon the step before to be completed. They are also known as cycle charts or cyclical maps.

A relations diagram also shows an event or process that has a number of different steps, but these steps do not always depend upon the step before to be completed. Relations diagrams identify and represent relationships between causes of events; cycle maps just sequence them. Both diagrams help you see patterns in the events.

FIGURE 4.65 a. A cycle map **b.** A relations diagram



4.10.2 Show me

Follow these steps to create a cycle map or a relations diagram.

Choose a topic that has a number of events, which rely upon the previous step to occur.

1. List actions or steps that are relevant to a particular cycle on small pieces of paper.
2. Order your pieces of paper and then position the steps in a circle.
3. Review your cycle — are any steps in the wrong order, missing or irrelevant? If so, make changes.
4. Write your cycle with each step placed in a box and the boxes joined by arrows within your circle.

FIGURE 4.66 Cycle map of life cycle of a dog flea

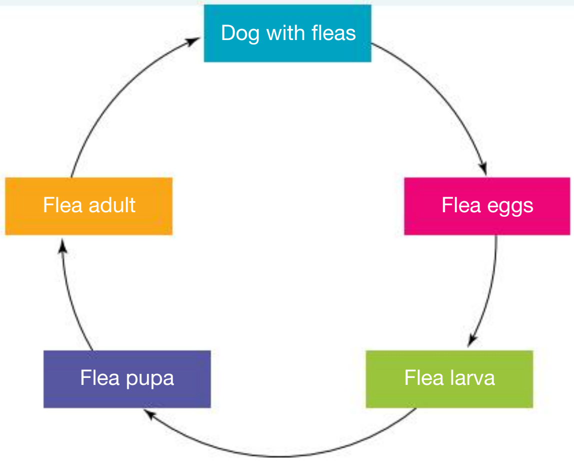
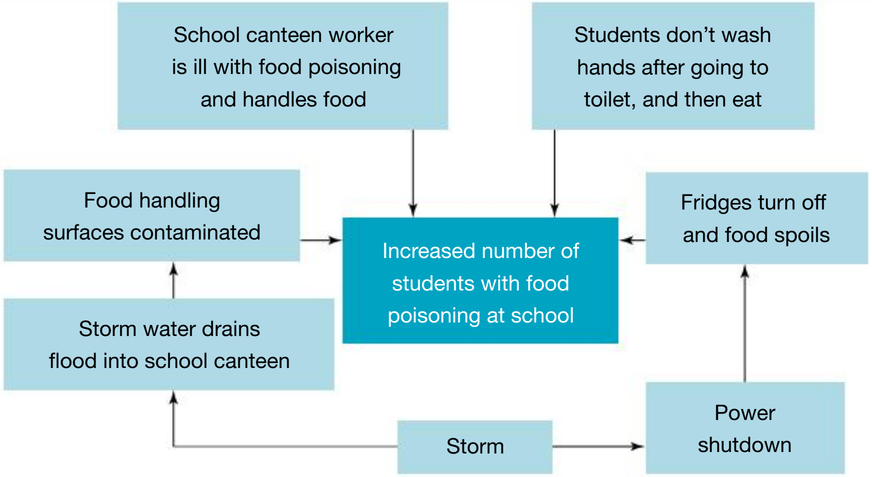


FIGURE 4.67 Relations diagram to show how food poisoning could occur in a school canteen.

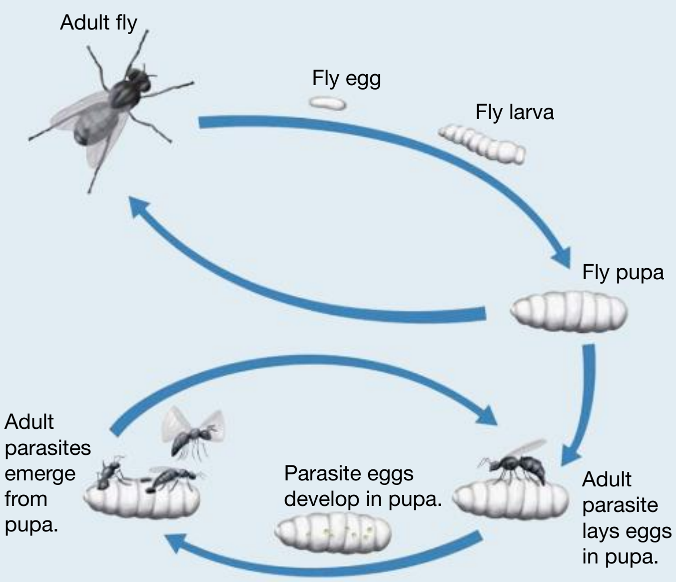


4.10.3 Let me do it

4.10 ACTIVITIES

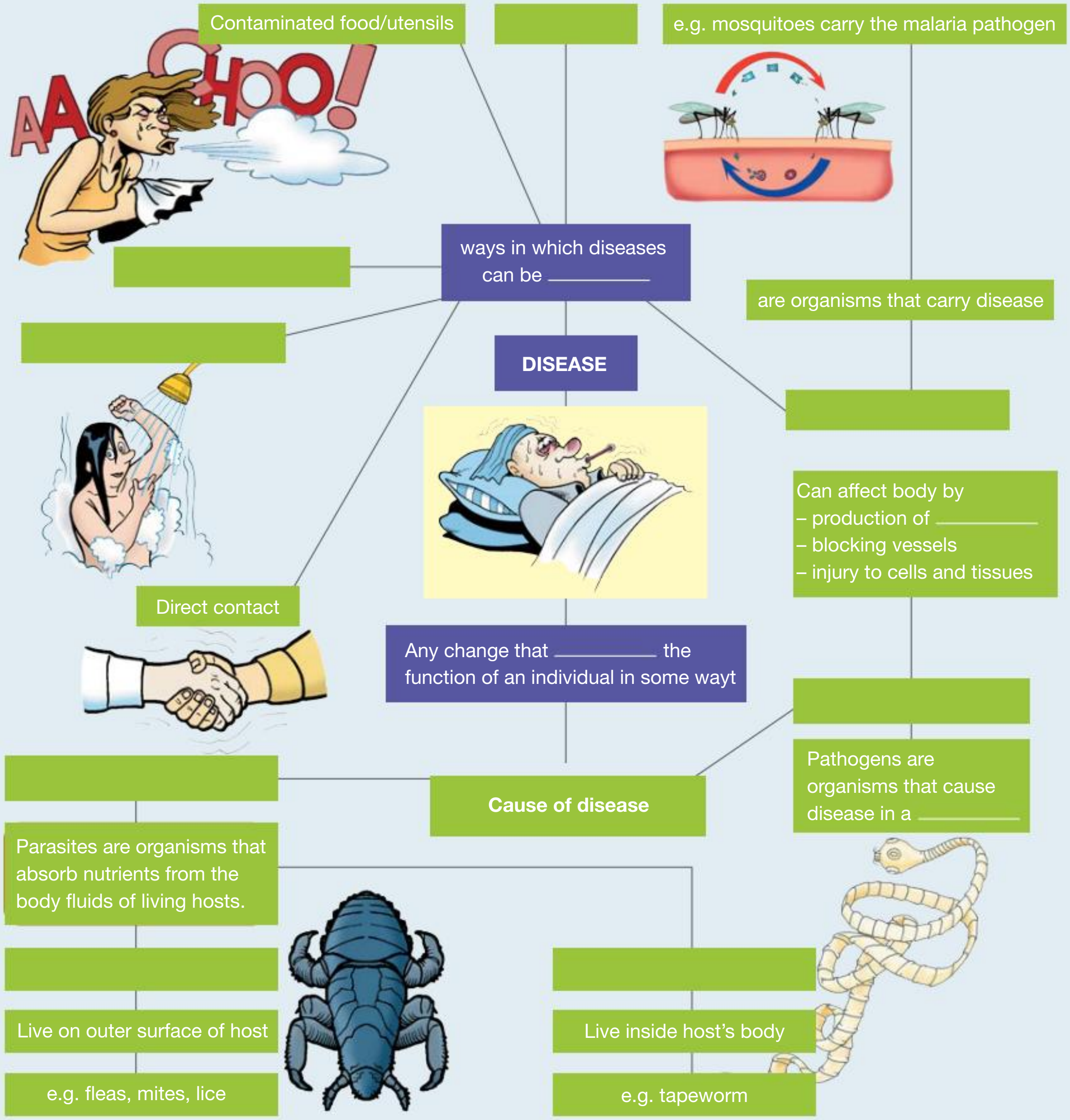
1. Use a cycle map or a relations diagram to show why the area around an infected cut becomes red and inflamed (swollen).
2. Biological control is a method of using one living organism to control another by interfering with its life cycle in some way. An example of this is using parasites to control fly populations. Use the diagram to answer the following questions.
   a. At which stage in the life cycle of the fly do the parasites invade?
   b. Suggest how the use of this method may control the fly population.
   c. Find out more about the use of biological control to reduce fly populations.

Parasites that use flies as hosts can be used to help control fly populations.



3. Examine the relations diagram below. Find out where the words in the top box fit in the relations diagram.

water	endoparasites	toxins
ectoparasites	transmitted	pathogen
air	impairs	blood
vectors	parasites	host



Fully worked solutions and sample responses are available in your digital formats.

4.11 Review

Access your topic review eWorkbooks

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-5197	ewbk-5199	ewbk-5201

on Resources

4.11.1 Summary

Catch us if you can

- Disease can be defined as any change that impairs the function of an individual in some way; it causes harm to the individual.
- Infectious diseases are diseases that are contagious and are caused by a pathogen.
- Non-infectious diseases cannot be spread from one person to another; they are not contagious (transferred from one organism to another).
- Some of the ways in which pathogens may be transmitted include direct contact, vectors, contaminated objects or contaminated water supplies.
- The spread of disease may be controlled by: personal hygiene; care with food preparation; proper disposal of sewage and garbage; chemical control of vectors; chemical treatment of clothes, surfaces and water; pasteurisation of milk; public education programs; quarantine laws; and the use of drugs such as antibiotics.

The good, the bad and the ugly

- There are trillions of microbiomes that love on us and in us; we need them, and they need us to survive.
- Parasites can cause harm to their hosts as they obtain resources from them.
- Parasites that can cause disease are also considered to be pathogens.
- Endoparasites live inside the body of its host organism.
- Ectoparasites lives outside the body of its host organism.
- Pathogens may be cellular (made up of cells) or non-cellular.
- Cellular pathogens include disease-causing bacteria, protists, fungi and animals.
- Non-cellular pathogens include viruses, prions and viroids.
- Malaria is one of the most serious public health problems worldwide that is a leading cause of death and disease in many developing countries.
- Mosquitoes are not only vectors for the malaria parasite, but can also transmit elephantiasis, dengue fever, yellow fever and Japanese encephalitis.

Historical medicine

- Hippocrates (c. 460–377 BC) was a Greek doctor who believed that everything was created from four elements: water, earth, air and fire, and that they were also linked to the four humours within the human body.
- Hippocrates and his disciples based their medical practice on reason and experiment and used diet and medication to restore the body's balance of humours.
- The Hippocratic Oath requires doctors to take care of the ill and not do them harm.
- Claudius Galen (c. AD 129–199), a Greek physician who lived in Rome, was influenced by Hippocrates. He believed that all diseases were caused by an imbalance in the elements or their associated body humours and that all cures must be based on correcting the imbalance.
- Medieval doctors were influenced by the ideas of Hippocrates and also linked each of the four body humours to the stars and planets.

- Medieval physicians used the knowledge of plants, astronomy, mathematics, four humours, chemical sciences and religion to create medicines.
- Medieval physicians considered the colour of urine helpful to a doctor's diagnosis of disease.
- Surgeons also used cupping that involved placing hot metal glasses or cups on a patient's cut skin, in the belief that poisons would be released from the body into the cup, to treat diseases.
- Models, theories, knowledge and experiments of early scientists have provided us with an awareness of our world and the opportunity to explore it that was unavailable to them.

Zooming in — microscale and nanoscale

- The microscope was invented in 1609; this opened up a whole new world of discovery.
- Robert Hooke (1635–1703) observed a sliver of cork under the light microscope and noted a pattern of tiny regular holes that he called cells.
- Technological advances in optics led to the production of compound microscopes that produced clear images by mid-nineteenth century.
- Works of Matthias Schleiden and Theodor Schwann led to the establishment of the cell theory — that all living things are made up of cells.
- Louis Pasteur (1822–1895) showed that microbes were around all the time and could cause disease. He also introduced vaccines for fowl cholera, anthrax and rabies.
- In 1867, Joseph Lister's work on microorganisms with infection, led to the use of disinfectants during surgery, reducing post-operative infections and death.
- In 1928, Alexander Fleming (1881–1955) discovered the antibiotic penicillin — opening the era of 'wonder drugs'.
- A nanometre is one billionth of a metre, or $\frac{1}{1000000000}$ m.
- Tiny human-made nanoparticles (about 0.1–100 nanometres) are currently being developed to deliver drugs directly to cancer cells.
- Relenza is an example of an anti-influenza drug that was researched by Australian CSIRO scientists, which binds to the active site of neuraminidase; this prevents the virus from leaving the infected cell to infect other cells.

Outbreak

- Plagues are contagious diseases that have spread rapidly through a population and resulted in high death rates.
- Epidemics occur when many people in a particular area have the disease in a relatively short time.
- Pandemics are diseases that occur worldwide.
- Spanish influenza is a strain of influenza caused by the H1N1 subtype of influenza virus, which spread across the world in 1918–1920.
- Asian influenza is a strain of influenza caused by the H2N2 subtype of influenza virus, which spread across parts of the world in 1956–58.
- Avian influenza is a strain of influenza caused by the H5N1 subtype of influenza virus, which is highly contagious in birds and has caused over 300 fatalities in humans since 2003.
- Swine flu is a strain of influenza caused by the H1N1 subtype of influenza virus, containing a combination of genes from the swine, human and avian flu viruses, and killed several thousand humans in 2009.
- Coronaviruses are named for the 'corona' or crown of spikes on their viral envelope; these spikes bind to specific receptors on the host cell and cause respiratory tract infections.

Putting up defences

- Pathogens possess specific chemicals that are recognised as being non-self or foreign to your body, referred to as antigens, and trigger your immune response.
- The first and second lines of defence involve non-specific responses: they react the same to all infections and as they have no 'memory' of prior infections, their level of response will be the same for each infection with the same pathogen.

- The first line of defence that is designed to prevent the entry of invading pathogens is physical barriers (skin, coughing, sneezing, cilia and nasal hairs) and chemical barriers (body fluids such as saliva, tears, stomach acid and acidic vaginal mucus).
- The second line of defence comes into play when pathogens have managed to get through your first line of defence and involves inflammation and special types of white blood cells called phagocytes.
- Phagocytes engulf and destroy pathogens using a process called phagocytosis.
- The lymphatic system contains lymph vessels, lymph nodes, lymph and white blood cells. Some of these white blood cells are lymphocytes.
- The third line of defence involves specific responses: it reacts in a specific way to each infection and as it retains a 'memory' of prior infections there is a much greater response in future infections by the same pathogen.
- In the third line of defence, the presence of antigens can trigger some B lymphocytes to differentiate into plasma cells to produce and release specific antibodies against the antigen.
- T lymphocytes are involved in the third line of defence and fight the pathogens at a cellular level. They also attack damaged and cancerous cells.
- In the third line of defence, memory cells may be formed from lymphocytes after infection with a pathogen — they 'remember' each specific pathogen encountered and are able to mount a strong and rapid response if that pathogen is detected again.

Immunity and immunisation

- Immunity is resistance to a particular disease-causing pathogen. A person who is immune does not develop the disease.
- Vaccination or immunisation is the giving of the vaccine to produce a type of immunity called artificial immunity.
- Poliomyelitis is a highly infectious disease caused by the *Picornaviridae* virus that can have consequences including complete recovery, limb and chest muscle paralysis, or death.
- Active immunity is achieved by your body making antibodies to a specific antigen.
- Passive immunity is achieved by your body receiving antibodies from an outside source, such as from your mother's milk or through vaccination with antibodies.
- Human papilloma virus (HPV) is the cause of greater than 90 per cent of cervical cancers.
- Professor Ian Frazer from the University of Queensland's Centre for Immunology and Cancer Research developed a vaccine for the HPV, which may eradicate cervical cancer.

Our noble Nobels

- Penicillin is a powerful antibiotic substance found in moulds of the genus Penicillium that kills many disease-causing bacteria without harming the body's natural defences.
- In 1945, Howard Florey shared the Nobel Prize with Alexander Fleming and Ernst Chain for extracting penicillin.
- Antibiotics destroy bacteria, and they are widely used to treat diseases caused by bacteria.
- Immunology is the branch of science that deals with immunity from disease.
- Immune system is a network of interacting body systems that protects against disease by identifying and destroying pathogens and infected, malignant or broken-down cells.
- Professor Peter Doherty shared the Nobel Prize in 1996 with Rolf Zinkernagel for describing the way the immune system recognises virus-infected cells.

4.11.2 Key terms

active immunity immunity achieved by your body making antibodies to a specific antigen
antibiotic a substance derived from a micro-organism and used to kill bacteria in the body
antibodies any of various proteins that are produced by B lymphocytes as a result of the presence of a foreign substance in the body and that act to neutralise or remove that substance
antigen a substance that triggers an immune response
Asian influenza a strain of influenza caused by the H2N2 subtype of influenza virus, which spread across parts of the world in 1956–58
avian influenza a strain of influenza caused by the H5N1 subtype of influenza virus that is highly contagious in birds and has caused over 300 fatalities in humans since 2003
B lymphocyte part of the third line of defence, these lymphocytes may be triggered by antigens to differentiate into plasma cells that produce and release specific antibodies against the antigen; also known as B cells
bacillus a rod-shaped bacterium
Black Death *see* bubonic plague
bubonic plague an infectious, epidemic disease, caused by the *Yersinia pestis* bacteria and carried by fleas from rats; also known as the Black Death
cell the smallest unit of life and the building blocks of living things
cellular immune response immunity involving T lymphocytes (assisted by phagocytes) that actively destroy damaged cells or cells detected as non-self, such as those triggering an immune response
cellular pathogen a pathogen that is made up of cells, such as a tapeworm, fungus or bacterium
clonal selection theory a model for how the immune system responds to infection and how certain types of B and T lymphocytes are selected for destruction of specific antigens invading the body
coccus a spherical bacterium
dendrimer a molecule that forms the basic structure of a nanoparticle
disease any change that impairs the function of an organism in some way and causes it harm
DNA (deoxyribonucleic acid) a substance found in all living things that contains genetic information
ectoparasite parasite that lives outside the body of its host organism
endoparasite parasite that lives inside the body of its host organism
epidemic a disease affecting a large number of people in a particular area in a relatively short period of time
fungi organisms, such as mushrooms and moulds — some help to decompose dead or decaying matter and some cause disease
gut flora bacteria and other organisms that live inside the intestines and help digest food
Hippocratic Oath an oath historically taken by doctors that requires them to follow ethical rules and principles
host organism living in a relationship with another organism
humoral immune response immunity involving antibodies (which are specific to a particular antigen) that are produced and secreted by B lymphocytes that have differentiated into plasma cells
immune system a network of interacting body systems that protects against disease by identifying and destroying pathogens and infected, malignant or broken-down cells
immunisation administering an antigen, such as in a vaccine, with the aim of producing enhanced immune response against the antigen in a future exposure
immunity resistance to a particular disease-causing pathogen
immunology the branch of science that deals with immunity from disease
infectious disease a disease that is contagious (can be spread from one organism to another) and caused by a pathogen
inflammation a reaction of the body to an infection, commonly characterised by heat, redness, swelling and pain
intermediate host the organism that a parasite lives in or on in its larval stage; also known as secondary host
lymphatic system the body system containing the lymph vessels, lymph nodes, lymph and white blood cells that is involved in draining fluid from the tissues and helping defend the body against invasion by disease-causing agents
lymphocyte small, mononuclear white blood cells present in large numbers in lymphoid tissues and circulating in blood and lymph
memory cells cells that may be formed from lymphocytes after infection with a pathogen — they 'remember' each specific pathogen encountered and are able to mount a strong and rapid response if that pathogen is detected again
microbiome the community of microorganisms (such as bacteria, fungi, and viruses) living together in a particular habitat

micrometre one millionth of a metre
nanoparticle a microscopic particle about 0.1–100 nanometres in size
moulds types of microscopic fungi found growing on the surface of foods
nanometre one billionth of a metre
non-cellular pathogen a pathogen that is not made up of cells, such as a virus, prion or viroid
non-infectious disease a disease that cannot be spread from one organism to another
obligate intracellular parasite a parasite that needs to infect a host cell before it can reproduce
pandemic a disease occurring throughout an entire country or continent, or worldwide
parasite organism that obtains resources from another organism (host) that it lives in or on, and can cause harm to
passive immunity immunity achieved by your body receiving antibodies from an outside source, such as from your mother's milk or through vaccination
pathogen a disease-producing organism
penicillin a powerful antibiotic substance found in moulds of the genus *Penicillium* that kills many disease-causing bacteria
phage a type of virus that infects and kills bacteria
phagocyte white blood cell that ingests and destroys foreign particles, bacteria and other cells
phagocytosis the ingestion of solid particles by a cell
plagues contagious diseases that spread rapidly through a population and results in high mortality (death rates)
plasma cell *see* B lymphocyte
poliomyelitis a highly infectious disease caused by the *Picornaviridae* virus that can have consequences including complete recovery, limb and chest muscle paralysis, or death
primary host the organism that a parasite lives in or on in its adult stage
prion an abnormal and infectious protein that converts normal proteins into prion proteins
quarantine strict isolation of sick people from others for a period of time (originally 40 days) in order to prevent the spread of disease
RNA (ribonucleic acid) complex compound that functions in cellular protein synthesis and replaces DNA as a carrier of genetic codes
Spanish influenza a strain of influenza caused by the H1N1 subtype of influenza virus, which spread across the world in 1918–1920
spirochaete a spiral-shaped bacterium
surface protein a protein molecule occurring on the surface of a virus
swine flu a strain of influenza caused by the H1N1 subtype of influenza virus, containing a combination of genes from the swine, human and avian flu viruses
T lymphocyte part of the third line of defence, these lymphocytes fight the pathogens at a cellular level. Some T lymphocytes may also attack damaged, infected or cancerous cells.
transmissible spongiform encephalopathy (TSE) a degenerative neurological disease caused by prions
vaccination administering a vaccine to stimulate the immune system of an individual to develop immunity to a disease
variolation deliberate infection of a person with smallpox (Variola) in a controlled manner so as to minimise the severity of the infection and also to induce immunity against further infection
vector an organism that carries a pathogen between other organisms without being affected by the disease the pathogen causes
viroid non-cellular pathogen comprised solely of a short circular RNA without a protein coat
virus a very simple microorganism that infects cells and may cause disease
white blood cells living cells that fight bacteria and viruses

on Resources

eWorkbooks	Study checklist (ewbk-5203) Literacy builder (ewbk-5204) Crossword (ewbk-5206) Word search (ewbk-5208)
Practical investigation eLogbook	Topic 4 Practical investigation eLogbook (elog-0669)
Digital document	Key terms glossary (doc-34981)

4.11 Exercise

learnON

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 9, 10, 15	Questions 4, 5, 6, 11, 14, 16, 17, 21	Questions 7, 8, 12, 13, 18, 19, 20, 22

Remember and understand

1. Identify which type of diseases can be transmitted from one person to another.
2. MC Identify the term used for the cause of an infectious disease.
   A. Accidents B. Ageing C. Nutritional deficiency D. Pathogen
3. MC Identify the term used for any foreign particles that stimulate an immune response.
   A. Antibodies B. Antigens C. Lymphocytes D. Vaccination
4. MC Identify chemical barriers involved in the first line of defence against disease.
   A. Inflammation and fever B. Lymphocytes and antibodies
   C. Saliva and stomach acid D. Skin, cilia and nasal hairs
5. MC Identify the type of specific proteins that are produced rapidly and in great amounts during the secondary exposure response.
   A. Antibodies B. Antigens C. Lymphocytes D. Vaccination
6. MC Identify a way of tricking your immune system into acting as though it has met the pathogen before.
   A. Antibodies B. Antigens C. Lymphocytes D. Vaccination
7. MC Identify the type of acquired immunity in which a person makes their own antibodies after exposure to the antigen.
   A. Active artificial immunity B. Active natural immunity
   C. Passive artificial immunity D. Passive natural immunity
8. MC Identify the type of acquired immunity in which antibodies are injected into a person.
   A. Active artificial immunity B. Active natural immunity
   C. Passive artificial immunity D. Passive natural immunity
9. All parasites are pathogens. True or false? Justify your response.
10. Match the infectious disease with the type of pathogen that causes it.

Type of pathogen	Infectious disease
a. Bacteria	A. Malaria
b. Fungi	B. Measles
c. Protozoans	C. Ringworm
d. Viruses	D. Scarlet fever

11. Identify the types of cells that can divide into plasma cells and produce antibodies.
12. Describe what do helper T cells signal B cells to do?
13. Match the human blood component to its line of defence.

Line of defence	Blood component
a. First line of defence	A. Lymphocyte
b. Second line of defence	B. Phagocyte
c. Third line of defence	C. Platelet

Apply and analyse

14. Sequence the following cyclic events by matching them into order beginning with the infected person sneezing.
    A. Person infected
    B. Pathogens inhaled by uninfected person
    C. Infected person sneezes
    D. Pathogens released into air

15. Draw a flow chart to describe the host type in the life cycle of a parasite.
16. Draw a well label diagram to show the cycle of how a virus is spread.
17. Draw a well-labelled diagram to describe the malaria transmission cycle.
18. Explain how vaccines work.

Evaluate and create

19. Explain why are viruses such as HIV, cold, and flu so difficult to cure?
20. Construct your own summary mind maps or concept maps on the following topics, using the terms suggested (as well as any others that may be relevant).
    a. Infectious disease: contagious, infected, pathogen, cellular pathogens, non-cellular pathogens, quarantine, direct contact, vectors, contaminated objects, contaminated water, sneezing, coughing, physical contact, antibiotics, personal hygiene, tapeworms, head lice, fungi, protozoans, bacteria, viruses, prions
    b. Pathogens and parasites: parasite, host, primary host, intermediate host, endoparasite, ectoparasite, pathogen, non-cellular pathogen, cellular pathogen, prions, kuru, mad cow disease, viruses, obligate intracellular parasites, mumps, AIDS, warts, influenza, bacteria, coccus, bacillus, *Streptococcus*, cholera, pneumonia, typhoid, whooping cough, Gram stain, protozoans, malaria, amoebic dysentery, fungi, tinea, ringworm, thrush, worms and arthropods, tapeworm, liver fluke
21. Construct your own summary mind maps or concept maps on the following topics, using the terms suggested (as well as any others that may be relevant).
    a. Putting up defences: lines of defence, first line of defence, second line of defence, third line of defence, antigen, non-self, specific, non-specific, physical barriers, chemical barriers, inflammation, phagocytosis, phagocytes, white blood cells, inflammation, cilia, skin, acid, enzymes, nasal hairs, sneezing, coughing, lymphocytes, B lymphocytes, plasma cells, antibodies, T lymphocytes, lymphatic system, lymph, lymph vessels, memory cells
    b. Immunity: vaccine, vaccination, immunisation, active immunity, passive immunity, artificial immunity, natural immunity, antibodies, active natural immunity, active artificial immunity, passive natural immunity, passive artificial immunity
22. SIS Design an experiment that would show which disinfectants and antiseptics are most effective against the growth of bacteria in your kitchen.

Fully worked solutions and sample responses are available in your digital formats.

on Resources

eWorkbook Reflection (ewbk-3038)

teachon

Test maker
Create customised assessments from our extensive range of questions, including teacher-quarantined questions.
Access the assignments section in learnON to begin creating and assigning assessments to students.

RESOURCE SUMMARY

on Resources

Below is a full list of **rich resources** available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

4.1 Overview

eWorkbooks
- Topic 4 eWorkbook (ewbk-5182)
- Student learning matrix (ewbk-5184)
- Starter activity (ewbk-5185)

Practical investigation eLogbook
- Topic 4 Practical investigation eLogbook (elog-0669)

Video eLesson
- The body at war (eles-4188)

4.2 Catch us if you can

eWorkbooks
- Infectious diseases (ewbk-5187)
- Non-infectious diseases (ewbk-5189)

Video eLesson
- Airborne droplets (eles-2645)

Interactivity
- Classifying diseases (int-5768)

4.3 The good, the bad and the ugly

Practical investigation eLogbook
- Investigation 4.1: Microbes (elog-0671)

Video eLessons
- Human head lice on human hair (eles-2646)
- Malaria life cycle Part 1 (eles-4189)
- Malaria life cycle Part 2 (eles-4190)

4.6 Outbreak

Weblink
- COVID-19 data

4.7 Putting up defences

eWorkbook
- Labelling the body's first line of defence against disease (ewbk-5191)

Video eLesson
- Understanding HIV (eles-0125)

Interactivities
- T cells (int-5771)
- The first line of defence (int-5769)

4.8 Immunity and immunisation

eWorkbooks
- Immunity (ewbk-5193)
- Vaccination (ewbk-5195)

Video eLesson
- Immunisation in Australia (eles-0126)

Interactivity
- The body's response to antigens (int-5770)

4.11 Review

eWorkbooks
- Topic review Level 1 (ewbk-5197)
- Topic review Level 2 (ewbk-5199)
- Topic review Level 3 (ewbk-5201)
- Study checklist (ewbk-5203)
- Literacy builder (ewbk-5204)
- Crossword (ewbk-5206)
- Word search (ewbk-5208)
- Reflection (ewbk-3038)

Practical investigation eLogbook
- Topic 4 Practical investigation eLogbook (elog-0669)

Digital document
- Key terms glossary (doc-34981)

To access these online resources, log on to **www.jacplus.com.au**.

5 Ecosystems

LEARNING SEQUENCE

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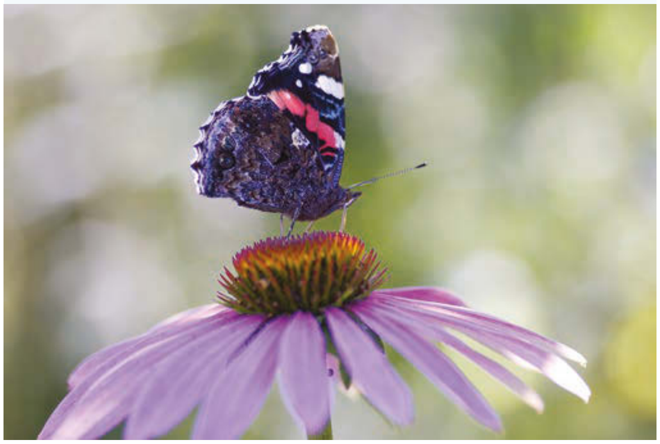
5.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

5.1.1 Introduction

Ecosystems are about relationships — the relationships between organisms as well as between organisms and the factors that make up their environments. Ecosystems are as large as the Amazon rainforest and as small as your garden. The butterfly and the flower in figure 5.1 have a relationship that benefits both organisms — the butterfly is feeding on the flower's nectar, and the flower is, in turn, being pollinated by the butterfly. In the study of ecosystems, we see the impact of one organism on another.

FIGURE 5.1 The butterfly and the flower have a relationship that benefits both organisms.



In this topic we will examine how ecosystems are studied and understood by scientists, the importance of plants as primary producers to all ecosystems and the relationships between different consumers — whether these are herbivores, carnivores, omnivores and detritivores. We will see that in all ecosystems there is a recycling of atoms and a flow of energy through complex food webs. We will also examine the effects of changes to ecosystems. Changes that can have an effect on ecosystems include removing or adding plants or animals. Non-living factors such as temperature, rainfall and fire, can also have significant effects on how an ecosystem functions and how plants and animals can evolve to suit their local ecosystem.

It is important to recognise the impact that we as humans have on our ecosystems, too. Australia has experienced severe droughts and fire seasons, and as the Earth continues to experience climate change, severe events such as these will continue to have huge impacts on all ecosystems.

on Resources

Video eLesson Butterfly and tropical flower (eles-2647)

Watch a video showing the relationship between a butterfly and a tropical flower.

5.1.2 Think about ecosystems

1. How do plants pull water from the ground?
2. Is being green essential for photosynthesis?
3. What happens to an ecosystem if a species disappears?
4. Why are bees under threat?
5. What is the role of bacteria in an ecosystem?
6. How does energy move through an ecosystem?

5.1.3 Science inquiry

Analysing rainfall data

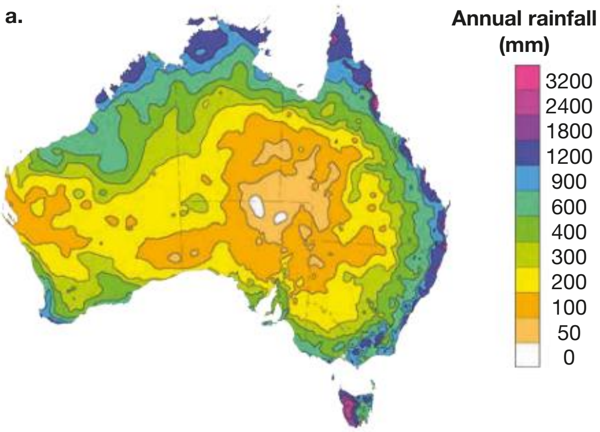
Organisms need water to survive. The good news is that water cycles through ecosystems. The bad news is that, at times, the amount of water available can be too great (as in the case of floods) or too little (as in the case of drought).

Some species have adapted to these conditions and possess adaptations that increase their chances of survival. Other organisms are not so well adapted and severe conditions of too much or too little water can result in their death. If too many of a particular type of organism die, then the decrease in their population size can have implications not only for other members of their food web, but also for other living (biotic) and non-living (abiotic) factors within their ecosystem.

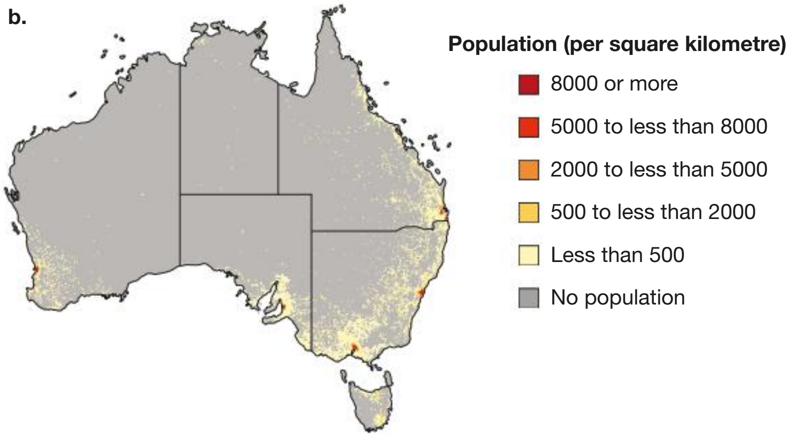
Your task is to analyse the patterns shown in the data in this section. Carefully examine the 2013 Australian rainfall figures and Australia's population distribution (figure 5.2). Australia is considered to be one of the driest continents on Earth, yet there is a variety of ecosystems within it. Use a range of resources to consider the following essential question: How can *where* an organism lives affect *how* it lives?

FIGURE 5.2 a. Annual rainfall data, 2013 **b.** Australia's population distribution, 2019

a.



b.



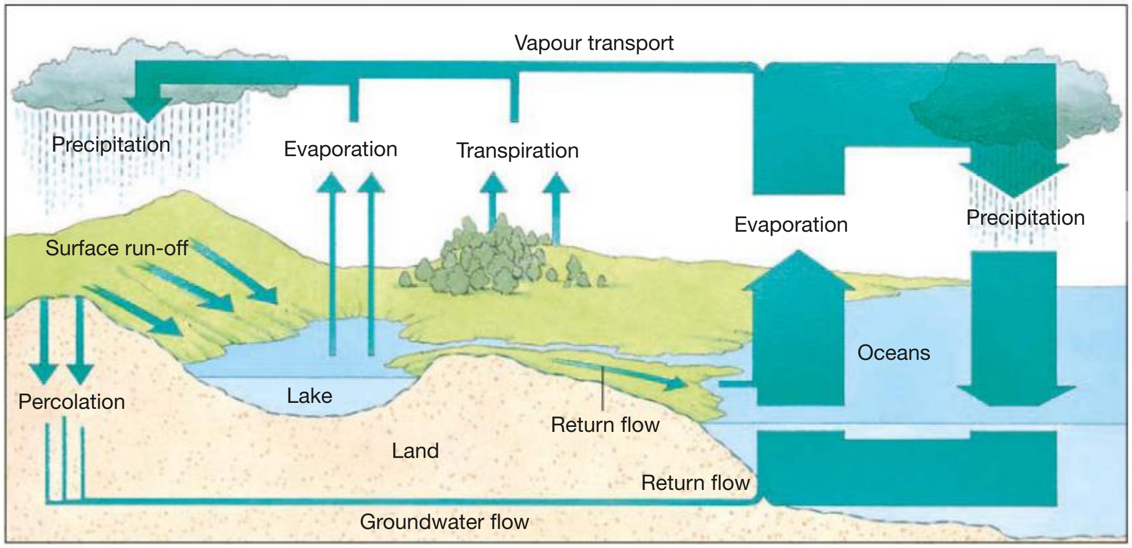
1. Discuss the distribution of Australia's human population with reference to the 2013 rainfall data.
2. Choose two animals or two plants. One organism should live in an area of annual rainfall shown by the blue shading, the other should live in the area with orange shading. State the rainfall for each colour and describe how each organism has special features of behaviours that enable it to live where it is found.

Use figure 5.3 to answer questions 3–5.

3. Is the movement of water by transpiration greater or less than the movement by evaporation from the ocean surface? (*Hint*: the wider the arrow the greater the amount of water that moves through that part of the cycle).
4. Describe the processes of evaporation and precipitation referring to states of matter.
5. Compare and contrast the two 'return flow' examples shown.

ewbk-3896
eles-2648
int-8257

FIGURE 5.3 Water cycles through ecosystems. The wider the arrow, the greater the amount of water that moves through that part of the cycle.



Resources

eWorkbooks

Topic 5 eWorkbook (ewbk-3915)
Student learning matrix (ewbk-3914)
Starter activity (ewbk-3917)

Practical investigation eLogbook

Topic 5 Practical investigation eLogbook (elog-0440)

learnon

Access and answer an online Pre-test and receive **immediate corrective feedback** and **fully worked solutions** for all questions.

5.2 Ecosystems

LEARNING INTENTION

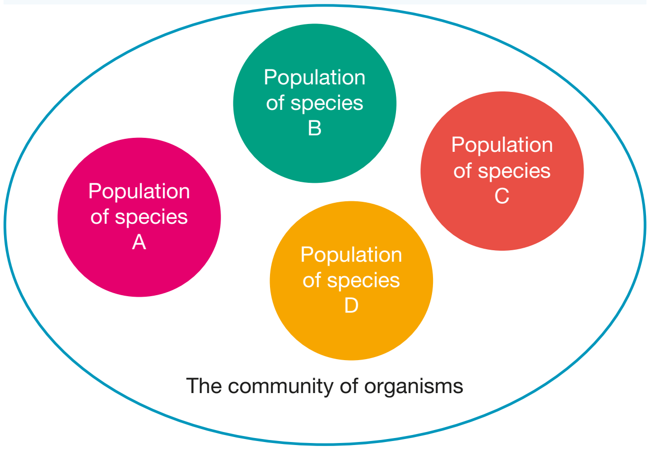
At the end of this subtopic you will recognise that ecosystems consist of different communities and populations of different species, and you will be able to name and describe the different relationships within and between these groups.

5.2.1 Living together

You may recall from your previous studies that everything in the universe is composed of atoms, which combine to form molecules. Some molecules have the ability to perform simple biological functions, and as these combine, there is an increase in the capacity to perform more complex functions. We can think of organisms in a similar way.

- You are a **multicellular organism** of the species *Homo sapiens*.
- You belong to a **population** when you are with others of your species in the same area at a particular time.
- You are described as part of a **community** when the population you are part of is living with many different populations of other species. There are different species of trees, shrubs, worms and so on. All these different species of organisms living together in the same place form the community.
- An **ecosystem** is when communities of organisms living together interact with each other and their non-living environment. They have a complex level of organisation, and can be described as having living (biotic) parts and non-living (abiotic) parts. The study of ecosystems is known as **ecology**.

FIGURE 5.4 Communities are made of populations of different species.



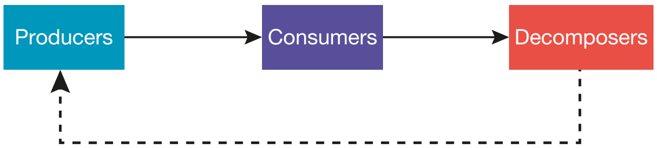
WHAT DOES IT MEAN?

The word *ecology* comes from the Greek terms *oikos*, meaning 'home', and *logos*, meaning 'study'.

5.2.2 Members of a community

The members of every community within an ecosystem can be identified as being either a **producer (autotroph)**, **consumer (heterotroph)** or **decomposer**. The feeding relationships between these groups can be shown in food chains or food webs (see subtopic 5.7).

FIGURE 5.5 Members of a community



Producers

Producers within ecosystems are essential as they are at the base of the food chain. Plants are producers. They use chlorophyll to capture light energy and use it to convert simple inorganic substances (carbon dioxide and water) into organic substances (glucose) in the process of photosynthesis. Since plants are able to convert glucose into other essential organic substances and do not need to feed on other organisms, they are often referred to as **autotrophs** ('self-feeders').

Luckily for all of us, plants also release oxygen gas as a waste product of photosynthesis. This molecule is essential for a type of cellular respiration called aerobic respiration — a process essential to the survival of the majority of organisms on our planet.

multicellular organism an organism that is made up of many cells

population a group of individuals of the same species living in the same area at a particular time

community more than one population living in the same area at a particular time

ecosystem communities of organisms that interact with each other and their environment

ecology the study of ecosystems

producer (autotroph) the organism at the base of the food chain that does not need to feed on other organisms

consumer (heterotroph) an organism that relies on other organisms for its food

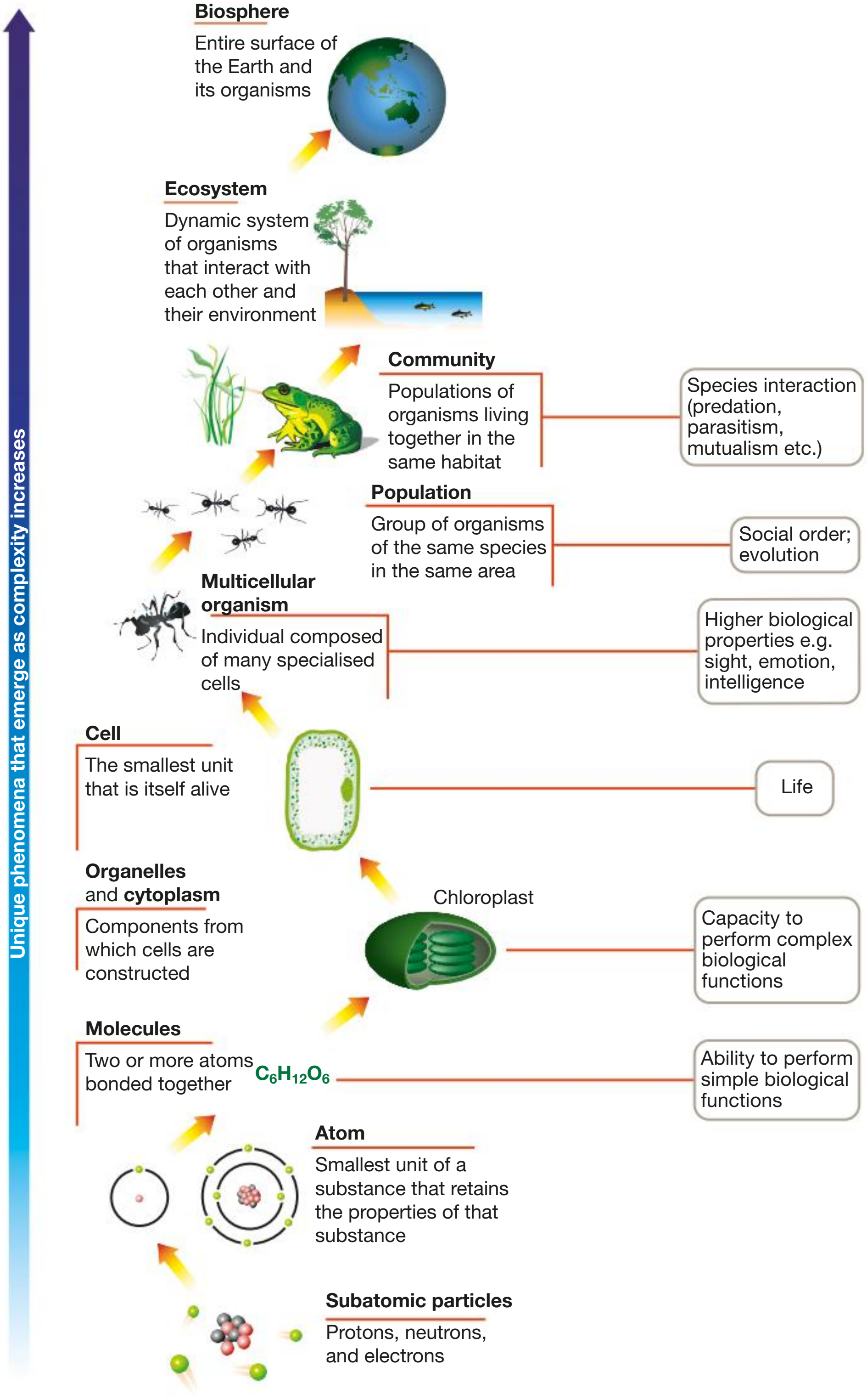
decomposer an organism that breaks down organic matter into inorganic materials

autotrophs *see* producer

WHAT DOES IT MEAN?

The word *photosynthesis* comes from the Greek terms *photo* meaning 'light' and *synthesis* meaning 'make'.

FIGURE 5.6 Levels of biological organisation. As each level increases, structural complexity increases and unique phenomena may emerge.



Consumers

Because they lack the chlorophyll required for photosynthesis, animals are unable to make their own food and are therefore called heterotrophs ('other-feeders'). As they obtain their nutrition from consuming or eating other organisms, they are called consumers. Consumers are divided into different types on the basis of their food source and how they obtain it.

- **Herbivores** eat plants and are often described as being **primary consumers** because they are the first consumers in a food chain. For example, koalas (figure 5.7).
- **Carnivores** eat other animals and are described as secondary or tertiary consumers in food chains or webs. For example, Tasmanian devils (figure 5.8).
- **Omnivores** eat both plants and animals. For example, humans.
- **Detritivores** feed on the tissue of dead or decaying organisms. For example, dung beetles.

herbivores animals that eat only plants

primary consumers the first consumers in a food chain; also known as a first-order consumers

carnivores animals that eat other animals

omnivores animals that eat plants and other animals

detritivores animals that feed on and break down dead plants or animal matter

FIGURE 5.7 The koala is a herbivore.

FIGURE 5.8 The Tasmanian devil is a carnivore.

Decomposers

While producers convert inorganic materials into organic matter, decomposers convert organic matter into simple inorganic materials. This is an example of how matter can be recycled within ecosystems so that they remain sustainable.

Fungi and bacteria are common examples of decomposers within ecosystems. These heterotrophs obtain their energy and nutrients from dead organic matter. As they feed, they chemically break down the organic matter converting it into simple inorganic forms or mineral nutrients. Their wastes are then returned to the environment to be recycled by producer organisms.

on Resources

Video eLessons Dung beetle relocating his dung house (eles-2649)
Decomposers (eles-2650)

5.2.3 Interactions between species

The **ecological niche** of each species is its specific role in the ecosystem. This niche includes its:

- habitat (where it lives within the ecosystem)
- nutrition (how it gets its food)
- relationships (interactions with both its own species and other species within the ecosystem).

ecological niche the role or position of a species or population in its ecosystem in relation to each other

Many different species can live together in a community because each species has a unique niche. For example, some animals may feed at night and others during the day, some may eat nectar whilst others eat leaves.

Interactions within an ecosystem may be betweenmembers of the same species or between members of different species. Examples of types of interactions include competition, predator–prey relationships andsymbiotic relationships.

FIGURE 5.9 The predator–prey relationship of a great white shark and a seal

Competition

Organisms with a similar niche within an ecosystem will compete where their needs overlap. **Competition** between members of different species for the same resource (for example, food or shelter) is referred to as **interspecific competition** ('inter' = between). Competition for resources between members of the same species (for example, mates) is referred to as **intraspecific competition** ('intra' = within).

Predator–prey relationship

In a **predator–prey relationship**, one species kills and eats another species. The predator does the killing and eating and the prey is the food source. Examples of predator–prey relationships include those between sharks and marine animals, fish and coral polyps, spiders and flies, and snakes and mice. How many others can you think of?

Herbivore–plant relationship

Plants cannot run away from herbivores! How then can they protect themselves against being eaten? Some plants protect themselves by using physical structures such as thorns, spines and stinging hairs; others use chemicals that are distasteful, dangerous or poisonous.

Symbiotic relationships

A **symbiotic relationship** (symbiosis) is a close *ongoing* relationship between *two organisms* of *different species.* At least one of the two organisms benefits from the symbiotic relationship. There are three types of symbiotic relationships: **parasitism**, **mutualism** and **commensalism**.

TABLE 5.1 Types of symbiotic relationships

Interaction	Species 1	Species 2
Parasitism	✓ (Parasite)	✕ (Host)
Mutualism	✓	✓
Commensalism	✓	0

✓ = benefits by the association; ✕ = harmed by the association; 0 = no harm or benefit

competition the struggle among organisms for food, territory and other factors

interspecific competition competition between organisms of the different species

intraspecific competition competition between organisms of the same species

predator–prey relationship a relationship between organisms in which one species (the predator) kills and eats another species (the prey)

symbiotic relationship a very close relationship between two organisms of different species. It may benefit or harm one of the partners.

parasitism an interaction in which one species (the parasite) lives in or on another species (the host) from which it obtains food, shelter and other requirements

mutualism the relationship between two different organisms in which both benefit

commensalism the relationship between organisms where one benefits and the other is unaffected

Parasite–host relationships

Parasites are organisms that live in or on a host, from which they obtain food, shelter and other requirements. Although the host may be harmed in this interaction, it is not usually killed. Some parasites are pathogens, meaning organisms that cause disease. This means that the functioning of their host is in some way impaired or damaged, resulting in disease. Parasites can be classified as:

parasite organisms that obtains resources from another organism (host) that it lives in or on, and can cause harm to

ectoparasite a parasite that lives on the outside of the body of its host organism

endoparasite a parasite that lives inside the body of its host organism

- **Ectoparasites** — ecto- means external, so these parasites live on their host and include: fungi, fleas, ticks, leeches and some species of lamprey. An example is the fungus that causes tinea or athlete's foot. The fungus secretes enzymes that externally digest the skin that it is attached to. It then absorbs the broken-down nutrients. This causes your skin to break and become red and itchy.
- **Endoparasites** — endo- means internal, so these parasites live inside their host and include flatworms such as *Echinococcus granulosus*, roundworms such as *Ascaris lumbricoides* or tapeworms. Their heads have suckers (and sometimes hooks) to firmly attach themselves to the walls of their host's intestine. They do not need a digestive system themselves as they live off the digested food within the intestine. Tapeworms vary in length from 1 cm to 10 cm. As each tapeworm contains both male and female sex organs, they don't need a mate to reproduce.

on Resources

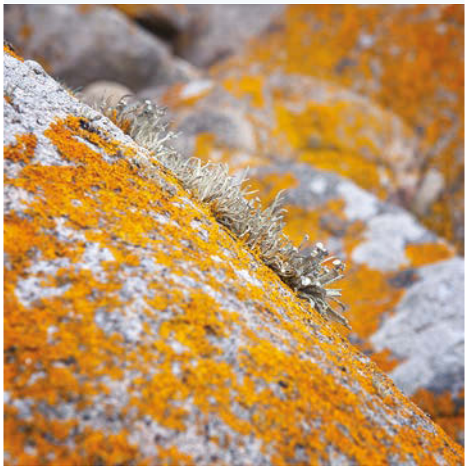
Video eLessons Jawed land leech (eles-2651)
Tapeworm in human intestine (eles-2652)

Parasitoids

Parasitoids ('-oid' means '-like') are organisms that are halfway between predators and parasites. While they act like parasites, they kill their hosts (usually another kind of insect) within a very short period. Examples of parasitoids are female insects that lay eggs inside the body of the host; when the eggs hatch, they eat the host from the inside. The host is killed when vital organs have been eaten. This relationship has applications in horticulture as a potential biological control method for pests feeding on crops. Examples of parasitoid organisms include wasps and flies.

FIGURE 5.10 Ant parasitoid wasp

FIGURE 5.11 Fungus and alga form a mutual relationship to create lichen.



Mutualism

Mutualism is an interaction between organisms of two different species in which they both benefit. In many cases, neither species can survive under natural conditions without the other. Lichen are often found growing on rocks or tree trunks and are made up of a fungus and an alga living together. The alga uses light energy from the Sun to make glucose (by photosynthesis) and the fungus uses this as food. The fungus shelters the alga so that it does not get too hot or dry out.

Commensalism

Commensalism is a relationship between two organisms where one organism receives benefit, but the other receives no benefit, but also no harm. This can be seen in the relationship between remora fish and sharks. Remora fish are often found swimming beneath sharks and benefit by being able to feed on leftover scraps; the sharks are not harmed but receive no benefit. The organism that benefits is referred to as the commensal and the other is sometimes referred to as the host. Clownfish and sea anemones are another example. While the clownfish (*Amphiprion melanopus*) lives among the tentacles of the sea anemone, it is unaffected by their stinging cells and benefits from shelter and any available food scraps.

FIGURE 5.12 Commensal clownfish and host anemone

on Resources

eWorkbook Food webs (ewbk-3898)

assess on Additional automatically marked question sets

5.2 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 4, 7, 10, 15	Questions 3, 6, 8, 12, 14, 16	Questions 5, 9, 11, 13, 17

Remember and understand

1. Define the term *ecology*.
2. What species do you belong to? Describe one relationship that your species participates in.
3. Define the term *ecological niche*.
4. a. Distinguish between herbivores, omnivores and detritivores.
   b. Distinguish between producers and decomposers.
   c. Identify two common examples of decomposers.
5. Complete the table to summarise the similarities and differences between parasitism, mutualism and commensalism.

Interaction	Species 1	Species 2
Parasitism		
Mutualism		
Commensalism		

✓= benefits by the association; X = harmed by the association;
0 = no harm or benefit

Apply and analyse

6. Explain why producers are essential to ecosystems.
7. In the interaction between a clownfish and a sea anemone, which organism benefits? Explain.
8. Use Venn diagrams to compare the following relationships.
   a. Commensalism and mutualism
   b. Parasitism and commensalism
   c. Predator–prey and parasite–host

9. Identify a type of organism that you may find in:
   a. a temperate marine kelp forest ecosystem
   b. a temperate closed forest ecosystem
   c. an Antarctic marine ecosystem.
10. Suggest why a parasite does not normally kill its host.
11. Use a Venn diagram to compare autotrophs and heterotrophs.
12. Is a mammalian embryo a parasite? Explain your answer.
13. a. List three examples of predators and then match them to their prey.
    b. Suggest structural, physiological and behavioural features that may assist:
       i. predators in obtaining food (for example, webs, senses, behaviour)
       ii. prey in avoiding being eaten (for example, camouflage, mimicry, behaviour, chemicals).

Evaluate and create

14. Construct a continuum to arrange the following in terms of increasing complexity: biosphere, cell, population, molecules, organisms.
15. Construct a flow chart that shows the relationship between producers, consumers and decomposers.
16. Use a flow chart to describe how a parasite obtains its food.
17. SIS Predict whether the following relationships are examples of parasitism, commensalism or mutualism.
    a. A dog with a tapeworm in its intestine
    b. Egrets living near cows
    c. Harmless bacteria *Escherichia coli* living in human intestines
    d. Root nodules of clover contain bacteria — the clover benefits, but can survive without the bacteria; the bacteria don't live anywhere else
    e. A fungal disease on human skin, such as ringworm

Fully worked soulations and sample responses are available in your digital formats.

5.3 Measuring biodiversity

LEARNING INTENTION

At the end of this subtopic you will know how to use sampling methods such as quadrats, transects and the capture–recapture method to determine density and/or distribution of populations in a community.

5.3.1 Mapping ecosystems

A **habitat** is the name given to the place where an organism lives. It needs to be convenient and provide conditions that are comfortable to the functioning of cells and life processes of its inhabitants. The match between the environmental conditions and the needs of organisms is responsible for the **population distribution** and **population density** of species within it.

An ecosystem may contain many habitats. It is made up of living or **biotic factors** (such as other organisms) and non-living or **abiotic factors** (such as water, humidity, temperature, light and pH) that interact with each other. There are several ways scientists can measure ecosystems.

Tolerance — The key to survival

Each species has a range of conditions in which an organism can survive. This is the **tolerance range** for each abiotic factor. The **optimum range** within the tolerance range is the one in which a species functions best. Measuring the abiotic factors in a habitat can provide information on the abiotic requirements for a

habitat where a species lives within the ecosystem

population distribution the area inhabited by a plant or animal species

population density the number of a species living within an area

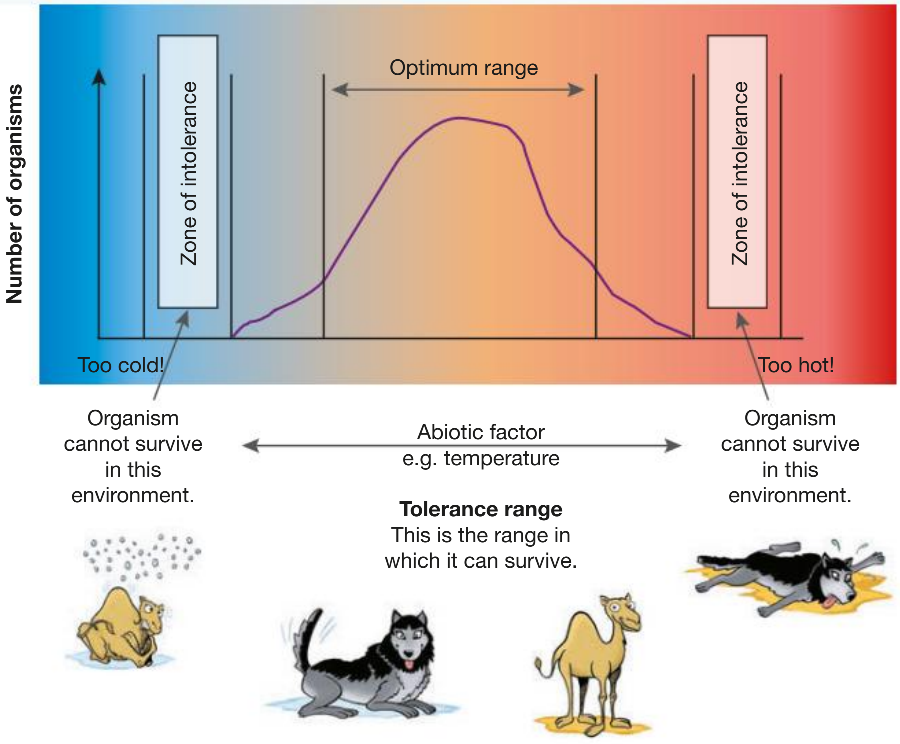
biotic factors the living things (organisms) in an ecosystem

abiotic factors the non-living features in an ecosystem

tolerance range the range of an abiotic factor in the environment in which an organism can survive

optimum range the range, within a tolerance range for a particular abiotic factor, in which an organism (of a particular species) functions best particular organism in that habitat. Can you think of features that organisms possess to increase their chances of survival in some habitats more than in others?

FIGURE 5.13 Measurement of a tolerance range for the abiotic factor of temperature



How many species and where are their habitats?

Investigation of an ecosystem involves studying how different species in it interact. To do this, you need to:

1. identify the organisms living in the ecosystem by using keys and field guides
2. determine the number or density of different species in the particular area; this indicates the biological diversity (**biodiversity**) within the ecosystem
3. determine the distribution of the different species or where they are located.

biodiversity the variety of species of biological organisms, often in relation to a particular area

sampling methods techniques used to determine the density and distribution of various populations and communities within an ecosystem

quadrats a sampling method used to estimate the distribution and abundance of organisms that are stationary or nearly stationary. The sampling area is typically 1 square metre.

How do you measure the biodiversity of an ecosystem?

Different **sampling methods** are used to determine the density and distribution of various populations in the community within the ecosystem:

- **Quadrats** can be used to estimate the distribution and abundance of organisms that are stationary or do not move very much. A quadrat is just a sampling area (often 1 square metre) in which the number of organisms is counted and recorded. When organisms are counted in a number of quadrats, this is usually considered to be representative of the total area under investigation. The average density of the total area can be estimated using the equation shown:

Estimated average density of total area

$$\text{Estimated average density} = \frac{\text{total number of individuals counted}}{\text{number of quadrats} \times \text{area of each quadrat}}$$

For example, if the total number of individuals counted is 100, number of quadrats is 4, area of each quadrat is 1 m^2, then

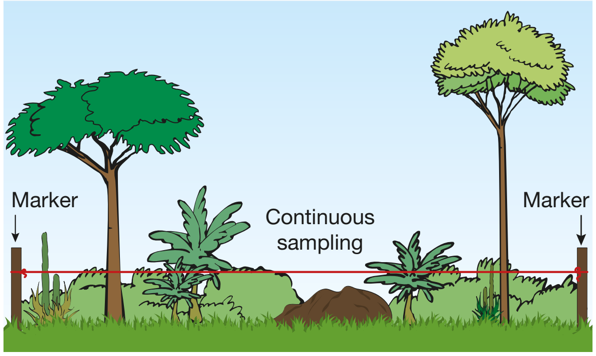
$$\text{Estimated average density} = \frac{100\ \text{individuals}}{4\ \text{quadrats} \times 1\ \text{m}^2} = 25\ \text{individuals/m}^2$$

- **Transects** are very useful when the environmental conditions vary along the sample under investigation (figure 5.14); for example, a sandy shore at the beach. The quadrats are placed at regular intervals along a line.
- The **capture, mark, release and recapture** sampling method is used to determine the abundance of mobile animals. A random sample of the population is captured and marked or tagged, then released and recaptured. This is also known as the capture–recapture method.

transects used to sample an area along a straight line, and is useful when environmental conditions vary along the sample line

capture, mark, release and recapture a sampling method used to determine the abundance of mobile animals

FIGURE 5.14 Line transects provide information on the distribution of a species in a community.



Resources

Interactivities Quadrat method (int-0984)
The capture–recapture method (int-0985)

elog-0320

INVESTIGATION 5.1

Using quadrats

Aim

To estimate the abundance of eucalypts in two different habitats

The maps of habitats A and B show each eucalyptus tree as a star.

Materials

- maps of habitats A and B (available in the resources panel of your online resource)
- transparent sheet
- scissors
- calculator

Method

1. Measure the length and width of each map and calculate the area of each using the following equation.

$$\text{Area} = \text{length} \times \text{width}$$

2. Make a quadrat by cutting a 3 cm × 3 cm square out of transparent sheet. Calculate the area of the quadrat.
3. Close your eyes and drop the quadrat anywhere on the map. Count how many eucalypts (crosses) are inside the quadrat. Repeat four more times. Do this for both maps.
4. Estimate the abundance of eucalypts in each environment using the equation:

$$\text{Estimated average density} = \frac{\text{total number of individuals counted}}{\text{number of quadrats} \times \text{area of each quadrat}}$$

Results

1. Complete the table.

TABLE Number of eucalypts per quadrat

	Number of eucalypts	
Quadrat number	Habitat A	Habitat B
1		
2		
3		
4		
5		
Average		

2. Include a labelled map of each habitat (Habitat A and Habitat B) with the quadrats marked in pencil and labelled Q1, Q2, Q3, Q4 and Q5 on each habitat.
3. **a.** Area of the map of habitat A was ______ cm.
   b. Area of the map of habitat B was ______ cm.

Discussion

1. State the average number of eucalypts in each habitat. Ask your teacher for the actual abundance of eucalypts in each habitat. Compare your estimate with the actual abundance.
2. Account for any difference in the density of eucalypts in each habitat. (*Hint:* are there any differences in abiotic factors?)
3. Suggest what you could have done to make your estimate more reliable.

Conclusion

Write a brief conclusion, remembering to state the data and refer back to the aim.

elog-0322

INVESTIGATION 5.2

Measuring abiotic factors

Aim

To investigate some abiotic factors in two different environments

Materials

- water samples A and B and soil samples A and B (provided by your teacher)
- thermometer
- dropper bottle of universal indicator solution
- universal indicator colour chart
- dropper bottle of silver nitrate solution (0.1 M)
- calcium sulfate powder
- test tubes

Method

1. Measure the water temperature (°C) of water samples A and B using a thermometer.
2. Test the pH of the water.
   - Pour 5 mL of tap water sample A into a test tube. Add 3 drops of universal indicator. Compare the colour of the water with the colour chart and record the pH of the water sample. Repeat using water sample B.
3. Measure the temperature (°C) of soil samples A and B using a thermometer.
4. Test the pH of the soil.
   - Place a small sample of soil A onto a watchglass. The soil should be slightly moist. If the soil is very dry, add a few drops of distilled water.
   - Sprinkle some calcium sulfate over the soil.
   - Add some drops of universal indicator over the calcium sulfate powder.

- Compare the colour of the powder with the colour chart and record the pH of the soil.
- Repeat using soil sample B.

5. Test the salinity of the water.
   - Pour 5 mL of water sample A into a test tube. Add 3 drops of silver nitrate solution. Note whether the sample remains clear, becomes slightly cloudy or turns completely white/grey.
   - Use the salinity test table below to work out the salinity of the water sample.
   - Repeat using water sample B.

TABLE Salinity test table

Description	Salinity
Clear	Nil
Slightly cloudy	Low
Completely white/grey	High

Results

1. Complete the table and add an appropriate title.

Abiotitc factor	Habitat A	Habitat B
Water temperature (°C)		
Soil temperature (°C)		
Water pH		
Soil pH		
Water salinity		

2. Construct column graphs that show the abiotic factor results for each habitat (habitat A and habitat B). For each graph, add a caption and title. For example, ‘Figure 1 Water temperature of habitats A and B.

Discussion

1. pH is a measure of the acidity of a substance. A pH of more than 7 is considered to be basic whereas a pH below 7 is considered to be acidic.
   a. Which water sample was most acidic? (Refer to the results table and graph.)
   b. Which soil sample was most acidic? (Refer to the results table and graph.)
2. If the soil was dry when testing its pH, distilled water was to be added. Why wouldn’t tap water be added to moisten the soil?
3. Identify any trends or patterns in your results. Suggest reasons for these patterns. (Refer to the results table and graph.)
4. Which of the tests in this investigation were qualitative and which were quantitative? Explain.
5. In which way were the variables controlled in this investigation? Refer to each abiotic factor.
6. Are the temperature results accurate for each environment? Explain.
7. Suggest two ways in which this investigation could be improved.
8. Design an investigation that could examine abiotic factors in your local school environment.

Conclusion

Write a brief conclusion, remembering to state the data and refer back to the aim.

elog-0324

INVESTIGATION 5.3

The capture–recapture method

Aim

To estimate population size using the capture–recapture method

Materials

- a large beaker
- red and yellow beads (substitute other colours if needed)

Method

1. In your notebook, draw a table similar to the one shown with enough room for 10 trials and the average.

TABLE Results of capture–recapture investigation

Trial	Number of untagged fish (red beads)	Number of tagged fish (yellow beads)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
Average		

2. Place about 200 red beads in the large beaker (you do not need to count them exactly at this stage). These represent goldfish living in a pond.
3. Catch 25 of the goldfish and tag them (replace 25 of the red beads with yellow beads).
4. Mix the beads thoroughly.
5. With eyes closed, one student should randomly select 20 beads from the beaker. These are the recaptured goldfish. Count how many fish are tagged (yellow beads) and untagged (red beads), and enter the numbers in the table.
6. Return the beads to the beaker and mix thoroughly. Repeat the above step a further nine times.

Results

1. Calculate the average number of tagged and untagged fish per capture.
2. Calculate the total number of fish using the equation:

$$\text{Population size} = \frac{n_1 \times n_2}{n_3}$$

where:
n_1 = number caught and initially marked and released
n_2 = total number recaptured
n_3 = number of marked individuals recaptured.

Discussion

1. State how many beads were actually in the beaker and compare the actual number to the number you calculated using the capture–recapture method.
2. List any source of errors in this experiment.
3. Why is the population size you calculated using this method an estimate?
4. Explain why this method can only be used for animals that move around. Why can't it be used to estimate the number of trees in a forest, for example?

Conclusion

Write a conclusion, remembering to state the data and link back to the aim.

elog-0326

INVESTIGATION 5.4

Biotic and abiotic factors

Aim

To measure biotic and abiotic factors in different areas in an environment

Materials

- access to a natural area in your school grounds or bushland near your school
- a data logger with temperature probe and light probe or a thermometer and hand-held light sensor
- wet–dry thermometer (or humidity probe for data logger)
- wind vane
- soil humidity probe (optional)
- calcium sulfate powder
- water in a small wash bottle
- Petri dish
- universal indicator
- string
- tape measure or trundle wheel
- sunhat and sunscreen

Method

Break up into groups. Each group will need to study a different area of the environment. Try to choose areas that are different (for example, sunny and shady areas, or near paths and away from paths).

Part A: Abiotic factors

1. Using the table in the results section, fill in the missing materials of equipment in the second column.
2. Use the equipment available at your school to measure the abiotic factors listed in the table. Complete the third column of the table.

Part B: Biotic factors

3. Use a trundle wheel to measure the length and width of the total area you are studying. If the area is too large to measure you may be able to estimate the surface area using a map.
4. Use the tape measure and string to cordon off an area 1 m by 1 m. This is your quadrat.
5. List all the different species you can see inside your quadrat. If you do not know their names, describe, photograph or draw them.
6. Decide which plant(s) you will count; you may wish to count clovers, for example. Count how many of this type of plant(s) are in your 1 m × 1 m square.

Results

TABLE Measurement of abiotic factors

Abiotic factor	Materials used/method	Measurement
Temperature		
Air humidity	Wet–dry thermometer	
Light intensity		
Soil humidity	Soil humidity probe (if available)	
Water pH	Refer to Investigation 5.2	
Soil pH	Refer to Investigation 5.2	
Water salinity	Refer to Investigation 5.2	

Part A: Abiotic factors

1. Sketch a map of the whole environment and show the locations of the different areas investigated. Label each area 'Group 1, 2' and so on. State which area your group investigated.
2. Display the average reading calculated for each abiotic factor measured in number 3 of the method in a table. Provide an appropriate name for the table.
3. Construct a column graph of the chosen abiotic factor showing the reading for each location studied. This is Figure 1; provide an appropriate name for this graph.

Part B: Biotic factors

4. Estimate the total number of each plant(s) counted using the equation below:

$$\text{Total number} = \frac{\text{average number per quadrat} \times \text{total area}}{\text{area of quadrat}}$$

Discussion

1. Identify any trends in the results you obtained in your abiotic factor observation. For example, how did the results for sunny areas compare with those for shady areas? (Refer to the results table and graph.)
2. Some organisms living in your quadrat cannot be seen.
   Give some examples. Why are these organisms very important? (Refer to the different members of a community in subtopic 5.2.)
3. Compare the class results for parts A and B. Identify any trends in the results. Is there a relationship between any of the abiotic factors and the type of organisms found? (Refer to the results table and graph.)

Conclusion

Write a brief conclusion, remembering to state the data and link to the aim.

on Resources

eWorkbooks Estimating the size of a population (ewbk-3900)
Abiotic factors in an ecosystem (ewbk-3902)

assess on Additional automatically marked question sets

5.3 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Distinguish between density and distribution.
2. Choose the correct words from the following list to fill the gaps in the sentence below: biotic, abiotic, density, distribution
   The term _______ describes where organisms are found and _______ is the number of a particular organism in that area.
3. Define each of the terms and provide an example.
   a. Habitat b. Ecosystem c. Abiotic factor

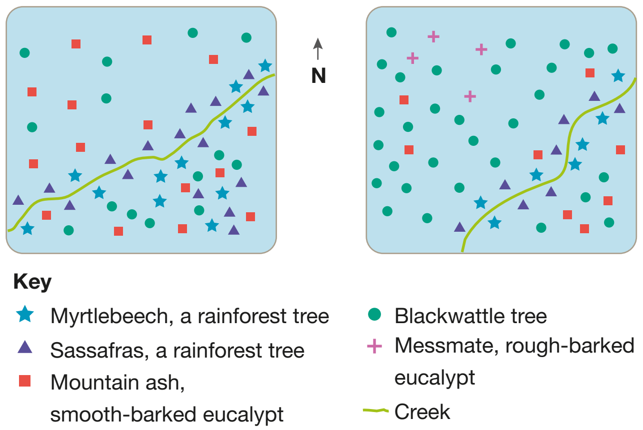
4. **MC** Identify the most appropriate sampling method to determine the distribution of organisms when the environment conditions vary along the sample under investigation.
   A. Capture–recapture **B.** Quadrants **C.** Quadrats **D.** Transects
5. Identify differences between the *environmental factors* and *environmental conditions*.

Apply and analyse

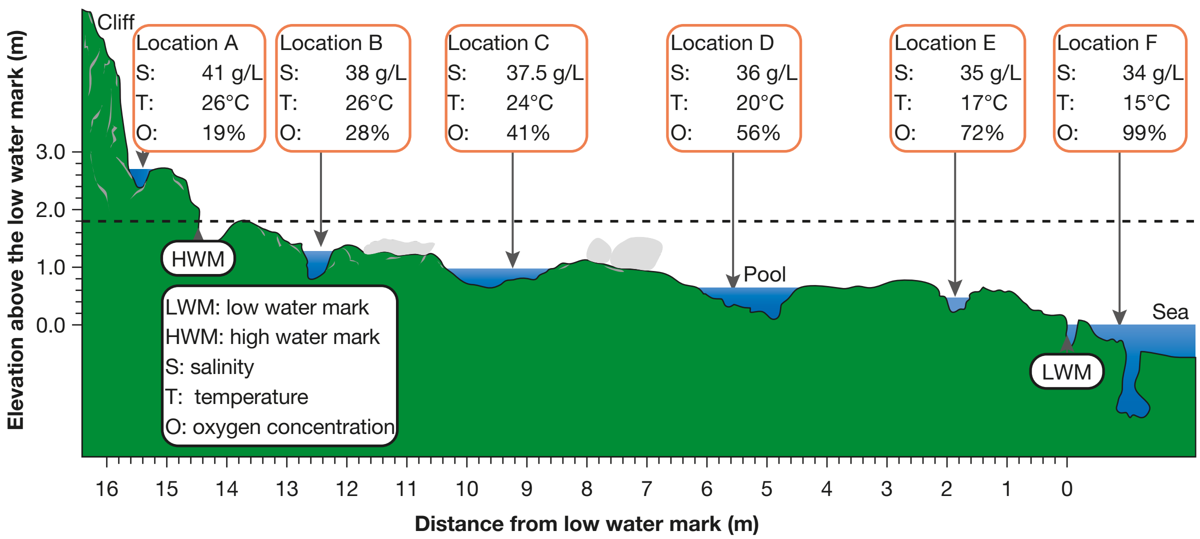
6. Explain the difference between a habitat and an ecosystem.
7. **a.** List five biotic factors that are part of the ecosystem.
   b. List five abiotic factors that are a part of the ecosystem in which you live.
8. Suggest ways in which a freshwater habitat may vary from a marine habitat. Relate these differences to the differences in features of organisms located in each habitat.

Evaluate and create

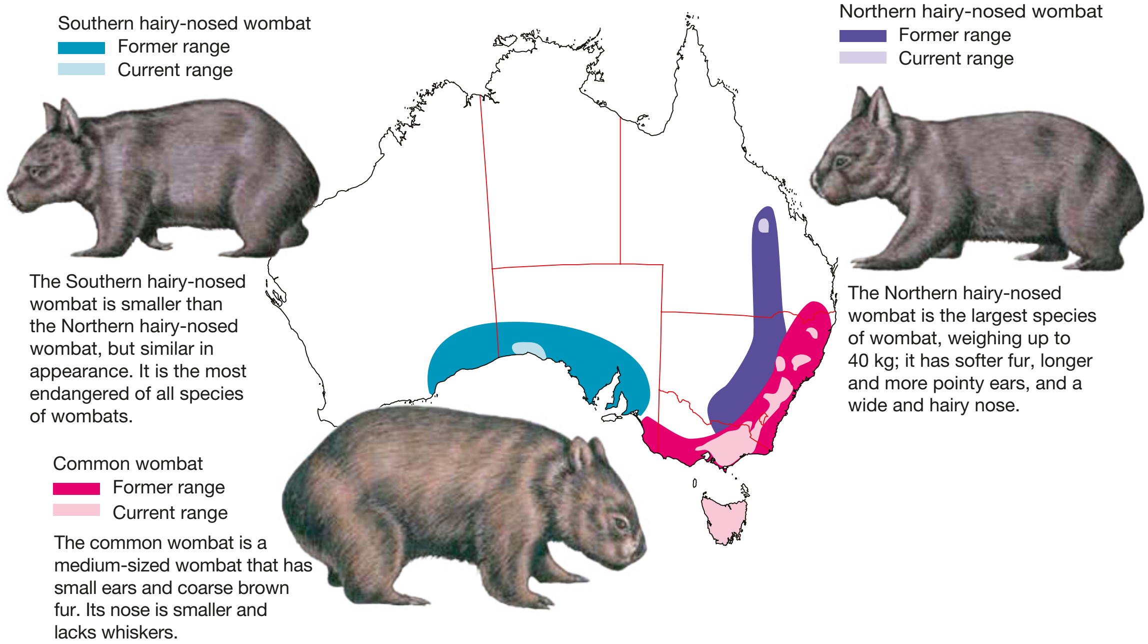
9. **SIS** The location of five different types of trees in the two quadrats below is indicated by the five different symbols.
   a. Count and record the number of trees in each quadrat.
   b. Count and record the number of the different species in each quadrat.
   c. Which quadrat provides the greatest variety of habitat types for wildlife? Give reasons for your response.
   d. Suggest why the rainforest species in both quadrats are located most densely near the creek.



10. **a.** **SIS** Carefully observe the diagram provided. Describe the patterns along the rock platform to the sea for each of the abiotic factors measured.
    b. Suggest the features that organisms living at these locations would need to possess.
    i. Location A **ii.** Location D **iii.** Location F



11. SIS Refer to the map showing the former and current range of three different species of wombat to answer the following.
   a. Suggest why wombats living in different areas have different features.
   b. Suggest how these differences may increase their chances of survival.
   c. Suggest reasons for the difference between their previous and recent habitat ranges.



12. Light intensity, water availability, temperature and dissolved oxygen levels are examples of abiotic factors that may be limiting factors in determining which organisms can survive within a particular habitat. Consider the details in the table provided and suggest responses for each of the blank cells.

TABLE Examples of habitats and adaptations of organisms to different abiotic factors

Abiotic factor	Abiotic factor description	Example of habitat	Features of organism that could survive
Light intensity	Low	Floor of rainforest	
Water availability	Low	Desert	
Temperature	Very high		
Dissolved oxygen levels	Low		

Fully worked solutions and sample responses are available in your digital formats.

5.4 Plants — the structure of the producers

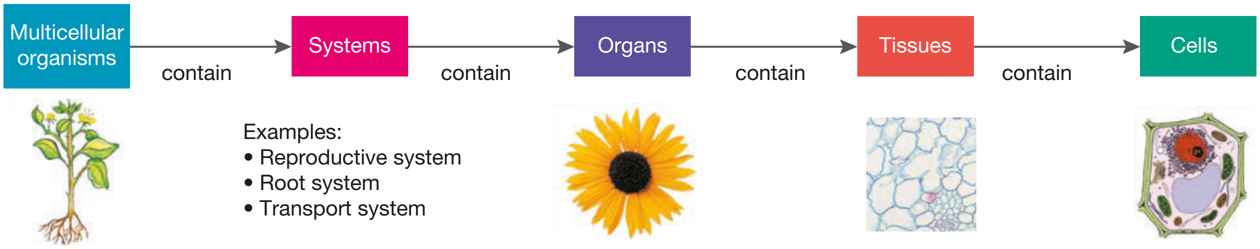
LEARNING INTENTION

At the end of this subtopic you will be able to describe the roles of different structures in plants that work together to keep the plant alive and to enable them to perform photosynthesis.

5.4.1 Plant organisation

Like other multicellular organisms, plants contain systems that help keep them alive. These systems are made up of organs. The main organs in vascular plants are roots, stems and leaves.

FIGURE 5.15 Multicellular organisms contain many components that work together to keep it alive.



Organs are made up of tissues, and tissues are made up of cells. Plant cells are eukaryotic cells; this means they have a membrane-bound nucleus. Cells are made up of specific structures with specific functions called organelles.

5.4.2 Plant organs

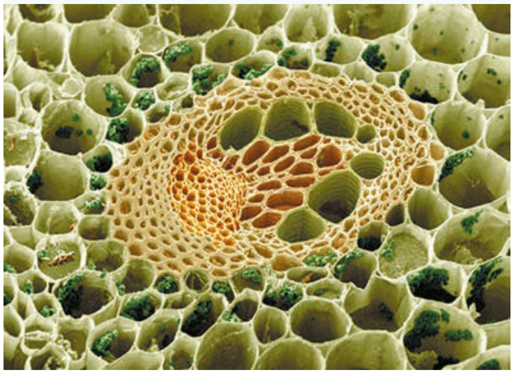
Roots

Roots both anchor plants and help them to obtain oxygen, water and mineral salts from the soil. **Root hairs** found on the outermost layer of the smallest roots can speed up this process by increasing the amount of surface area available for absorption. These long cells act like thousands of tiny fingers reaching into the soil for water and soluble salts. Look at the structure of plant roots (figures 5.16 and 5.17). The root hairs are a slender extension of an epidermal (outside layer) cell. While humans have an epidermal skin layer, plant roots are extensions of the epidermal layer of the root.

root hairs hairlike extension of epidermal cells on plant roots

FIGURE 5.16 Root hairs seen with an electron microscope

FIGURE 5.17 The vascular tissue of a dicot (buttercup) under an electron microscope



ewbk-3904

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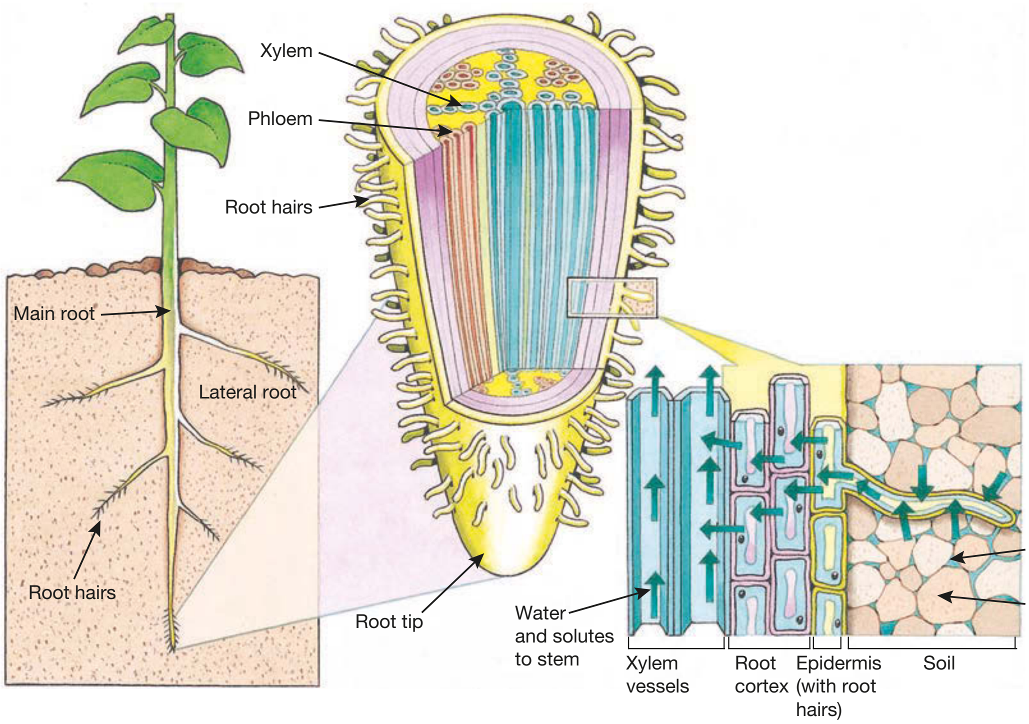
FIGURE 5.18 Root hairs of plants increase the surface area of the root to increase the oxygen, water and minerals a plant can absorb.



Stems

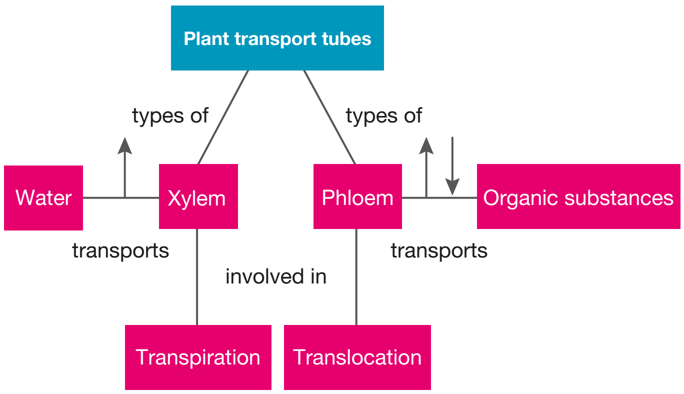
Plants stems act as a transport system and are made up of many thin tubes that transport liquids around the plant (figure 5.19). The two main types of tubes in vascular plants are the **phloem** and **xylem vessels**. These tubes are located together in groups called **vascular bundles**.

Plant transport

Translocation is the movement of organic compounds both up to the top of the plant and down to the roots of the plant, which can be seen in figure 5.19 with the up and down arrows. The two main types of organic molecules transported are nitrogenous compounds (for example, amino acids) and soluble carbohydrates (for example, sucrose).

How do plants pull water from the ground? How do trees grow so tall when they don't have a skeleton?

FIGURE 5.19 The plant transport system



phloem vascular tissue that transports organic substances (for example, sugars) within plants

xylem vessel vascular tissue that transports water and minerals from the roots up to the leaves

vascular bundle group of xylem and phloem vessels within a plant

translocation transport of materials, such as water and glucose, in plants

The **transpiration stream** is the transport of water up from the roots of the plant, though the xylem and out through the **stomata**. As this water vapour moves from the plant, suction is created that pulls water up through the xylem vessels from the roots. The loss of water vapour from the leaves (through their stomata) is called **transpiration**.

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

Leaves

Chloroplasts

A plant leaf is an organ that consists of tissues such as epithelial, vascular tissue and parenchyma tissue. The structure of cells within the tissues and the **organelles** that they contain can vary depending on the function of the cell. Leaf cells, for example, contain organelles called **chloroplasts**. Chloroplasts are found in the palisade layer just beneath the upper epidermis; this ensures they get a lot of sunlight. Chloroplasts contain **chlorophyll**, a green pigment that is involved in capturing or absorbing **light energy**. Chlorophyll traps the Sun's light energy. It is within the chloroplast that this light energy is transformed into the chemical energy in **glucose** molecules using the process of photosynthesis.

FIGURE 5.20 The composition of plant leaves

Flaccid or turgid

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

Stomata

The exchange of gases such as oxygen, carbon dioxide and water vapour between the atmosphere and plant cells occurs through tiny pores called stomata. These are most frequently located on the underside of leaves to reduce water loss. Evaporation of water (transpiration) from the stomata in the leaves helps pull water up the plant.

FIGURE 5.21 Surface view of a leaf showing stomata. Note the epidermal cells, guard cells and their chloroplasts, and stomal pores.

transpiration stream the movement of water through a plant as a result of loss of water from the leaves

stomata pores that exchange gases found on the surface of leaves. They are bordered by guard cells that change the size of the opening of the stomata (singular = stoma).

transpiration loss of water vapour mainly through stomata in the leaves (and sometimes from stems)

organelle a structure in a cell with a particular function

chloroplast oval-shaped organelle in plants that are involved in the process of photosynthesis, which results in the conversion of light energy into chemical energy

chlorophyll the green-coloured chemical in plants that absorbs the light energy so that it can be used in photosynthesis

light energy sunlight energy or energy from an artificial light source

glucose a six-carbon sugar (monosaccharide) that acts as a primary energy supply for many organisms

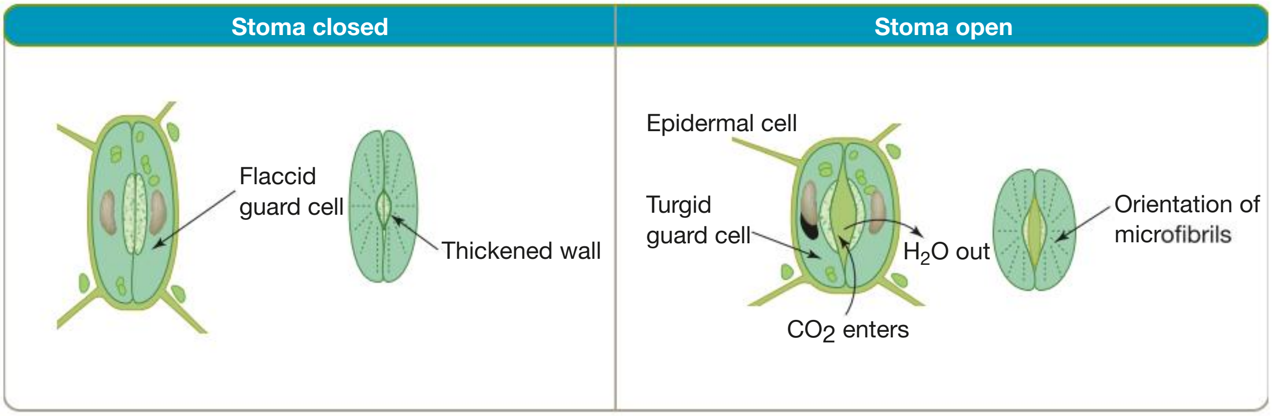
flaccid limp, not firm

turgid firm, distended

Guard cells that surround each stoma enable the hole to open and close, depending on the plant's needs (figure 5.22). When the plant has plenty of water, water moves into the guard cells, making them turgid. This stretches them lengthways, opening the pore between them (the stoma). If water is in short supply, the guard cells lose water and become flaccid. This causes them to collapse towards each other, closing the pore. In this way, the guard cells help to control the amount of water lost by the plant. Microfibrils in guard cells also influence the extent to which walls of guard cells can stretch.

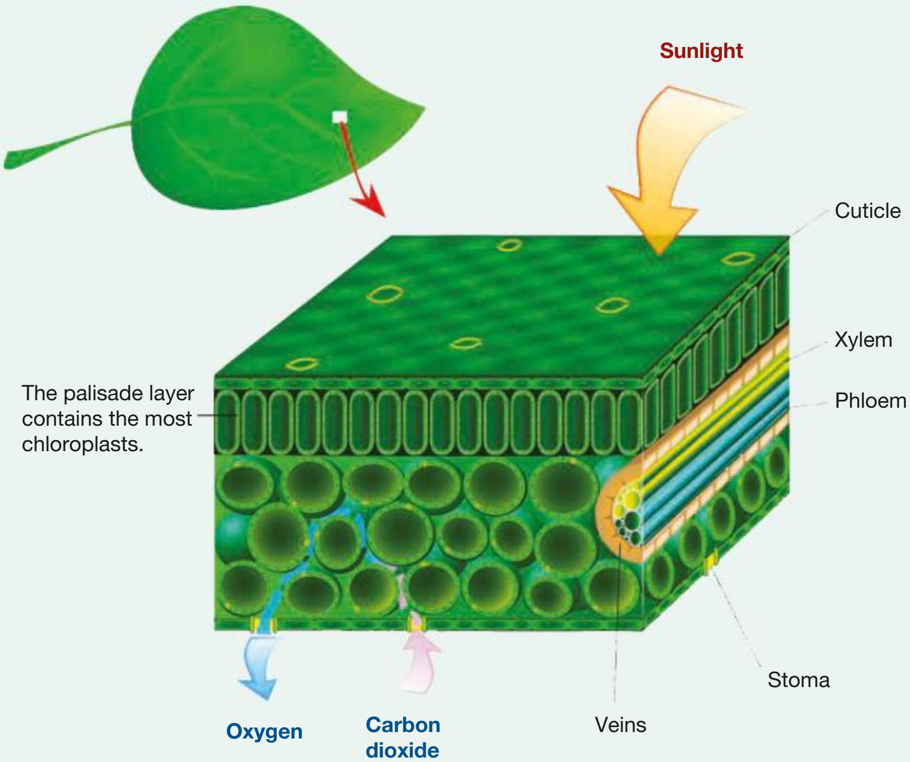
guard cells cells surrounding each stoma in a leaf enabling it to open or close depending on the availability of water

FIGURE 5.22 Inner and outer walls of guard cells may be of different thicknesses. A thinner outer wall can stretch more than a thicker inner wall. As the outer walls of guard cells stretch, the stoma (pore) opens



EXTENSION: Leaf anatomy

FIGURE 5.23 Transverse section through a portion of a leaf showing xylem and phloem tissue



Flowers

Flowers make up the reproductive structures of some plants. Within the flower there are structures that produce sex cells or **gametes**.

The male reproductive organ is the **stamen**. It contains:

- **anther** — produces the **pollen grains** (sperm)
- filament — supports the anther.

The female reproductive organ is the **pistil**. It is the collective term for the carpel. The carpel contains:

- **stigma** — pollination is the pollen grain landing on the stigma
- **style** — the tube that connects the stigma to the ovary
- **ovary** — produces the egg cells.

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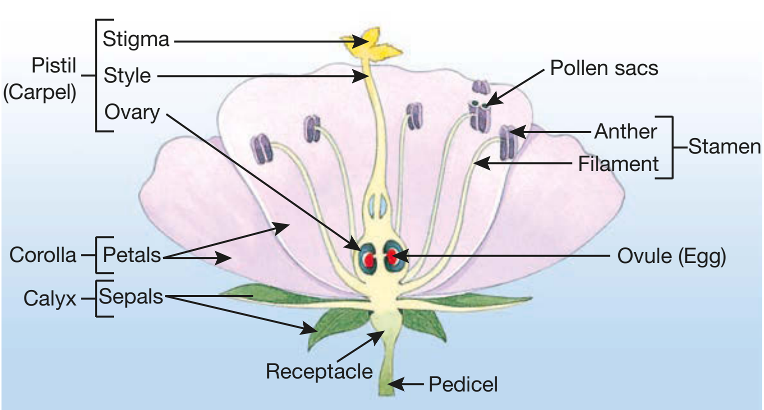
FIGURE 5.24 Parts of a flower. Note the presence of pollen-producing and egg-producing organs in the same flower



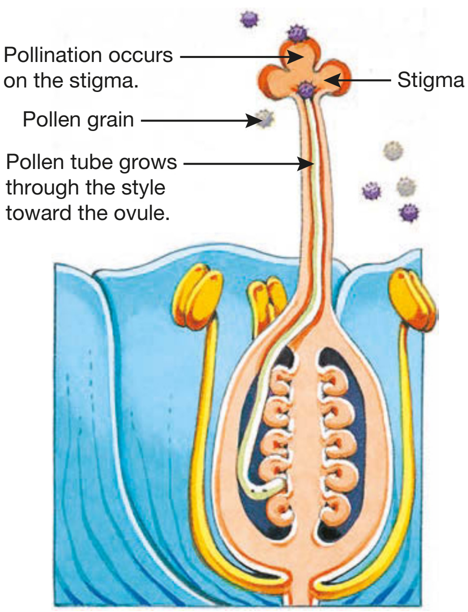
Pollination of flowering plants

Before the gametes can fuse together (**fertilisation**) to make a new plant, they need to find each other. First contact, or **pollination**, is achieved by the pollen grains landing on the **stigma**.

- **Self-pollination** is when a plant polinates itself.
- **Cross-pollination** occurs between different plants. It may involve not only other plants of the same species, but sometimes assistance from other species.

Following pollination on the stigma, the pollen grain grows through the style and merges with the egg cell to achieve fertilisation (figure 5.25).

FIGURE 5.25 Fertilisation in flowers is the fusing of the pollen grain and the ova.



flower the structure in flowering plants (angiosperms) that contains reproductive organs

gametes sex cells

stamen male reproductive organ of a flower, it consists of the anther and the filament

anther the part of a flower that produces pollen (the male gametes)

pollen grains the male gametes of a flower

pistil the female reproductive organ of a flower that consists of one or more carpel (made up of the stigma, style and ovary)

stigma a female reproductive structure in a flower that receives the pollen

style the tube-like female reproductive structure in a flower that connects the stigma to the ovary

ovary in flowering plants, is the hollow, lower end of the carpel containing the ovules (the female egg cells)

fertilisation fusion of the male sex cell and the female sex cell, in plants involves the fusion of pollen grain and egg cell

pollination the transfer of pollen from the stamen (the male part) of a flower to the stigma (the female part) of a flower

stigma a female reproductive structure in a flower that receives the pollen

self-pollination the transfer of pollen from the flower's own stamen to its stigma

cross-pollination the transfer of pollen from stamens of one flower to the stigma of a flower of another plant of the same type

Wind pollination

Pollen is transferred between some plants by the wind (**wind pollination**). The flowers of plants that use this type of pollination are usually not brightly coloured and have a feathery stigma to catch pollen grains, which were previously held on stamens exposed to the wind.

Animals as vectors

The flowers of plants that use animals as **vectors** to carry their pollen between plants are often brightly coloured and may reward the animal with food. In some cases, the reward may be sugar-rich nectar or protein-rich pollen. In other cases, the reward may have more of a sexual nature as some plants have evolved over time to mimic the sexual structures of their vector's potential mate.

wind pollination the transfer of pollen from one flower to another by the wind

vectors are organisms that carry and disperse reproductive structures (for example, pollen) of a different species; organisms that carry a pathogen between other organisms without being affected by the disease caused by the pathogen

insect pollination the transfer of pollen from one flower to another by insects

pollinators animals that transfer pollen from one flower to another

Insect pollination

Flowers that are pollinated by insects (**insect pollination**) are often blue, purple or yellow (colours that insects can see), possess a landing platform, have an enticing scent or odour and contain nectar offering a food supply to these hungry **pollinators** (figure 5.26). When the insects visit their next sweet treat of nectar on another flower, they transport pollen from their previous visit to the stigma of their new meal provider.

Bird pollination

Flowers that are pollinated by birds are often red, pink, orange or yellow (colours recognised by hungry birds as food) and possess petals in a tubular shape, with nectaries usually inside the base of the flower. As in insect pollination, the birds carry pollen from one meal to their next.

FIGURE 5.26 Bees act as vectors for pollination in some flowers

FIGURE 5.27 Anna's hummingbird pollinating a foxglove

on Resources

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5.4 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

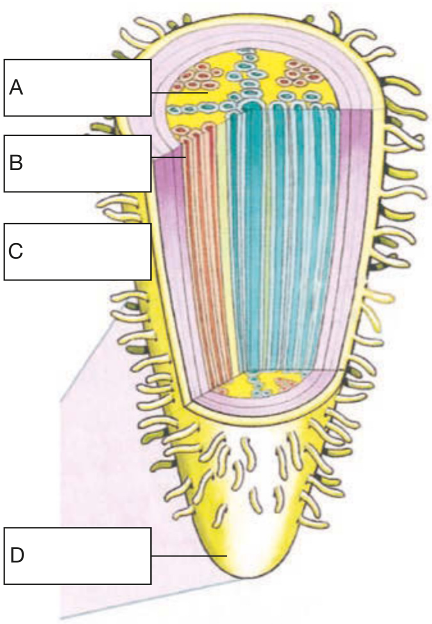
LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 3, 6, 8, 14	Questions 2, 5, 9, 12, 13	Questions 4, 7, 10, 11, 15, 16

Remember and understand

1. MC What is the name of the tubes that carry sugar solution around the plant?
   A. Xylem B. Root hair C. Phloem D. Stoma
2. Match each term with the appropriate example from the table below.

Terms	Examples
a. Organs	A. Chlorophyll
b. Cells	B. Chloroplasts
c. Organelles	C. Leaf cells
d. Molecules	D. Leaves

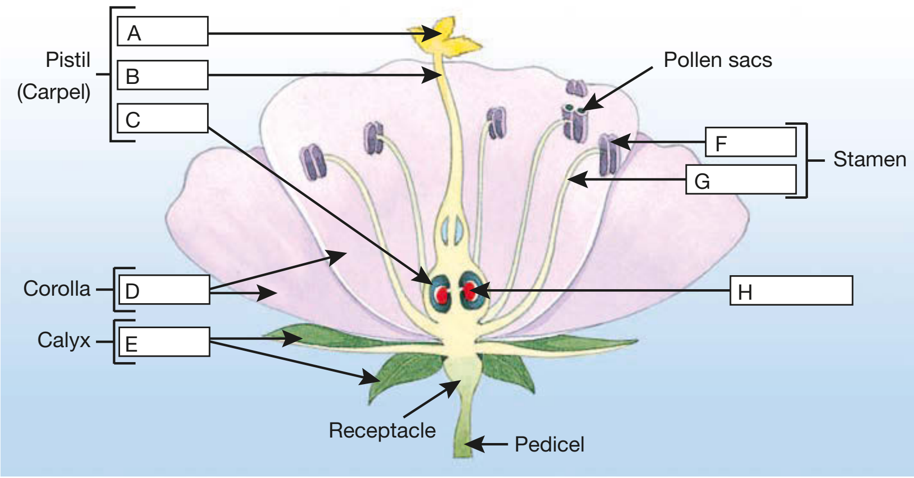
3. MC Identify the plant organ that anchors the plant and helps it to obtain oxygen, water and mineral ions from the soil.
   A. Flowers B. Leaves C. Roots D. Stem
4. MC Identify the specialised cells that are located on the outermost layer of the smallest roots with a shape that increases the surface area available for absorption of water and soluble salts from the soil.
   A. Guard cells B. Root hair cell C. Stomata D. Xylem
5. MC Identify the name given to the tiny pores through which gases and water vapour are exchanged between the atmosphere and plant cells.
   A. Chloroplasts B. Cuticle C. Sepal D. Stomata
6. Label the following diagram by placing the following terms in their appropriate positions. Phloem, Xylem, Root hairs, Root tip



7. What term describes the transport of water up from the roots of a plant, through the xylem and out through the stomata as water vapour?
8. Match each term with the appropriate description from the table provided.

Terms	Examples
a. Cross-pollination	**A.** Plants use the pollen that they produce to pollinate themselves
b. Fertilisation	**B.** Way in which the pollen grains reach the stigma of a plant
c. Pollination	**C.** Pollen from the flower of a different plant is used to pollinate the plant
d. Self-pollination	**D.** Fusion of male and female gametes

9. List the following terms from simplest to most complex.
   - Atoms
   - Cells
   - Molecules
   - Multicellular organisms
   - Organelles
   - Organs
   - Systems
   - Tissues
10. Fill in the missing terms to complete the labeling of the flower in the figure provided.



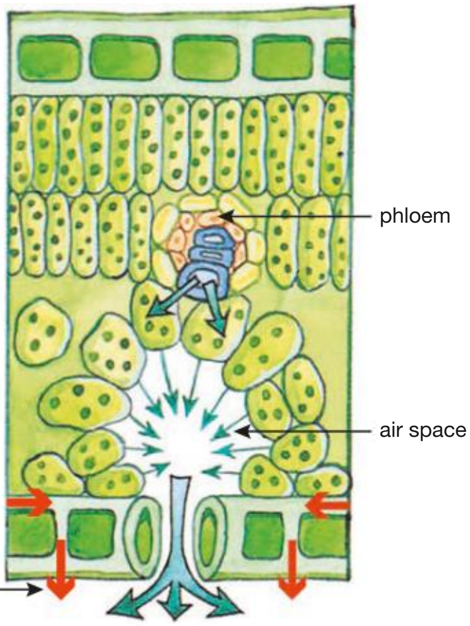
Apply and analyse

11. On which part of the plant are stomata usually found? Can you suggest why?
12. Explain why plant roots have small hairs.
13. **MC** Identify which type of pollination increases the variation among offspring, potentially giving them a better chance of survival.
    A. Cross-pollination
    B. Self-pollination
    C. Wind pollination
    D. Insect pollination

Evaluate and create

14. What is the most likely type of pollination used in plants with flowers that are not conspicuous, have no large scented petals or nectar, and possess anthers that hang outside the flower and feathery stigmas?

15. Add the following labels to the figure: cuticle, vascular bundle, water loss through stomatal pore, xylem, chloroplast, upper epidermis.
16. SIS How long do you think it would take for a plant to take up 50 mL of water? What conditions might speed it up? Put forward a hypothesis, and then design an experiment to test your hypothesis.



Fully worked solutions and sample responses are available in your digital formats.

5.5 Photosynthesis

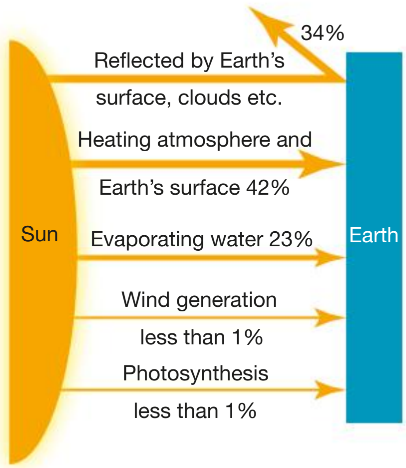
LEARNING INTENTION

At the end of this subtopic you will be able to describe the process of photosynthesis and how plants, as the key producers in ecosystems, use it to make their own food.

5.5.1 Solar powered

Did you know that life on Earth is solar powered? The source of energy in all ecosystems on Earth is sunlight. Plants play a very important role in catching some of this energy and converting it into a form that both they and other organisms can use.

FIGURE 5.28 Solar energy coming into Earth performs various functions.



5.5.2 Why are plants called producers?

Photosynthetic organisms such as plants, algae and phytoplankton are called producers or autotrophs because they can produce and use their own food. They use light energy to make complex, energy-rich organic substances from simpler inorganic substances (such as carbon dioxide and water).

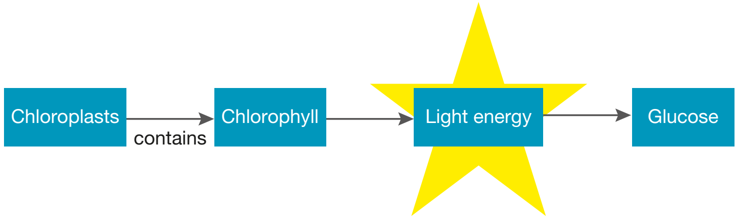
This process of capturing light energy and its conversion into chemical energy is called **photosynthesis** because it involves using light energy to synthesise glucose. Once it is in this chemical form, it can be used as food, stored as starch or converted into other organic compounds.

photosynthesis a series of chemical reactions in the chloroplasts of plant cells that uses light energy, carbon dioxide and water to produce oxygen, water and sugars (food)

5.5.3 Photosynthesis

The light energy captured by chlorophyll provides energy to split water (H_2O) molecules into oxygen and hydrogen. The oxygen is released as oxygen (O_2) gas into the atmosphere through the stomata. The hydrogen combines with carbon dioxide (CO_2) obtained through stomata from the atmosphere to make glucose ($C_6H_{12}O_6$).

FIGURE 5.29 Plants convert light energy into glucose through photosynthesis.



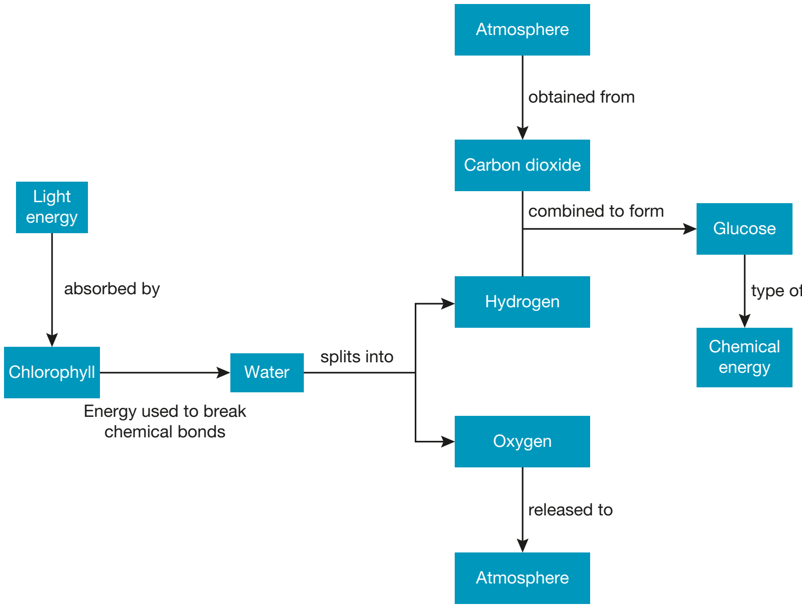
An overall chemical reaction for photosynthesis can written as:

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

It can also be represented in chemical symbols as:

$$6CO_2 + 12H_2O \xrightarrow[\text{chlorophyll}]{\text{light energy}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

FIGURE 5.30 The process of photosynthesis



5.5.4 Why are plants green?

Visible light consists of all of the colours of the rainbow! Of the whole spectrum, chlorophyll reflects only green light and absorbs other wavelengths of light (colours). It is for this reason that plants look green (figure 5.32). Look at the visible spectrum (colours of the rainbow) in figure 5.31. You can see that green is in the middle. However, being green is not essential to be able to photosynthesise. Some plants — algae and phytoplankton, for example — may contain light-capturing pigments that are red, yellow or brown. You can see in *Science as a human endeavour: Timeline of photosynthesis* that follows that Theodor Engelman found that red and blue light are the most important wavelengths (colours) for photosynthesis.

FIGURE 5.31 The spectrum of visible light

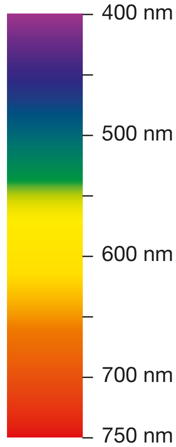


FIGURE 5.32 Plants are green due to the presence of chlorophyll.

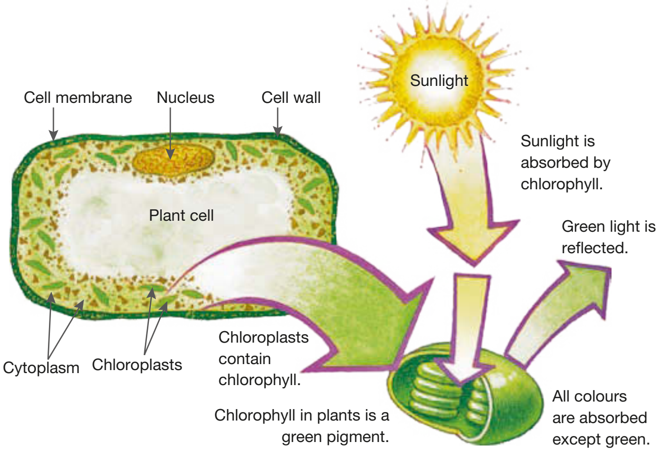
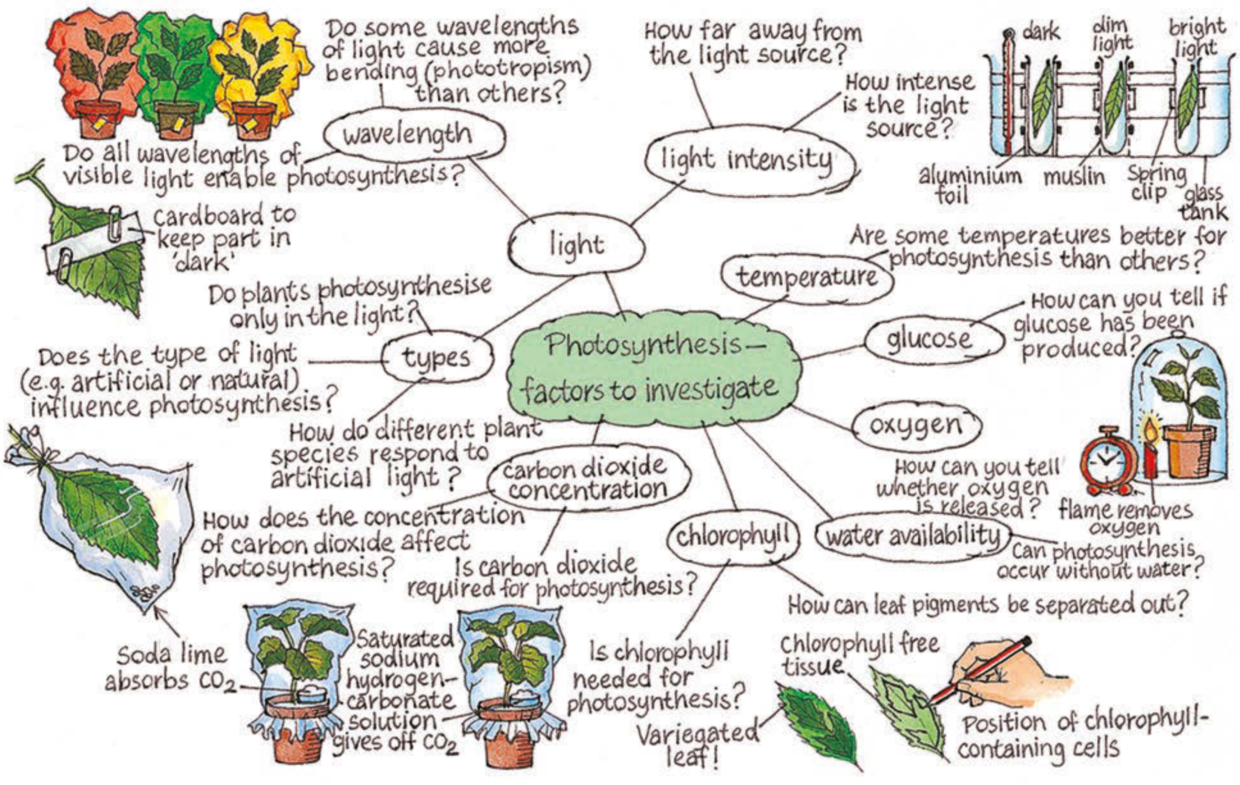


FIGURE 5.33 A mind-map exploring photosynthesis



SCIENCE AS A HUMAN ENDEAVOUR: Timeline of the discovery of photosynthesis

1450 — Nicholas of Cusa, German cardinal (1401–1464): Proposed idea that weight gained by plants is from water, not earth.

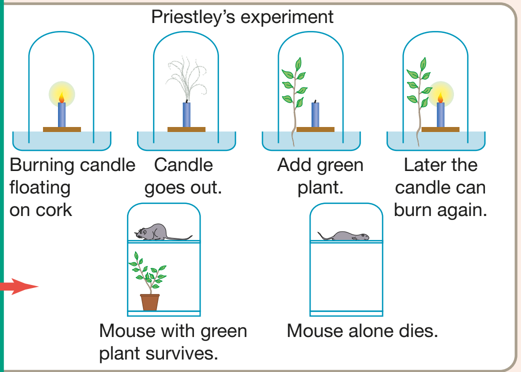
Jan Baptista van Helmont, Dutch physician (1577–1644): Demonstrated most material in a plant's body does not come from soil; suggested it comes from water.

1700

1720 — Stephen Hales, British physiologist/clergyman (1677–1761): Suggested plants get some nourishment from air.

1740

Joseph Priestley, British chemist/clergyman (1733–1804): Showed that plants could 'restore' air injured (by respiration).

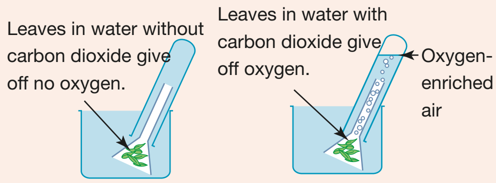


1760

1780 — Jan Ingenhousz, Dutch physician (1730–1799): Showed that plants need sunlight to restore 'injured air' and that only the green parts do this; all parts of plants 'injure' air (i.e. respire).

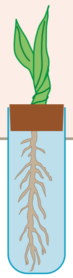
1800 — Various European chemists (late 18th century): Oxygen discovered and identified as 'restored' air; carbon dioxide discovered and identified as the 'injured' air.

Jean Senebier, Swiss minister (1742–1809): Plants use carbon dioxide dissolved in water as food.



1820

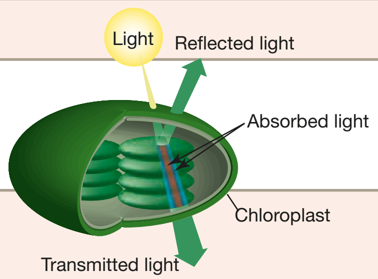
1840 — Julius von Sachs, German botanist (1832–1897): Discovered plant respiration, and that chlorophyll is found in chloroplasts; showed starch grains form during photosynthesis, and plants take in and use minerals from the soil; showed minerals were required for making chlorophyll.



Maize seedling held by the cork, with roots in the culture solution

1860

1880 — Theodor Wilhelm Engelmann, German physiologist (1843–1909): Showed that oxygen was produced by chloroplasts; and that red and blue light are the most important wavelengths for photosynthesis.



1900

elog-0328

INVESTIGATION 5.5

Looking at chloroplasts under a light microscope

Aim

To observe chloroplasts under a light microscope

Materials

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

Method

1 Using tweezers, carefully remove a leaf from a moss plant or take a small piece of spirogyra.
2 Place the leaf in a drop of water on a microscope slide and cover it with a coverslip.
3 Use a light microscope to observe the leaf. Draw and label the unstained leaf.
4 Put a drop of dilute iodine solution under the coverslip. (Iodine stains starch a blue–black colour.)
5 Using the microscope, examine the leaf again. Draw and label the leaf stained with iodine.

Results

1. a. Label the drawing of the unstained leaf 'Figure 1: Unstained leaf'. State the magnification. (Magnification = eyepiece × objective)
   b. Label the drawing of the leaf stained with iodine 'Figure 2: Stained leaf'. State the magnification. (Magnification = eyepiece × objective)
2. Label any chloroplasts that are present in figure 1 and figure 2.

Discussion

1. Describe the colour of the chloroplasts in figure 1.
2. What gives chloroplasts their colour?
3. a. Did the iodine stain any part of the leaf a dark colour?
   b. If so, what does this suggest?
4. What conclusions can you make about chloroplasts?
5. Identify the strengths of this investigation.
6. Suggest improvements to the design of this investigation.
7. Suggest a hypothesis that could be investigated using similar equipment. (You may use internet research to identify relevant problems to investigate.)
8. Design an experiment to test your hypothesis. Include an explanation for your choice and treatment of variables.
9. Share and discuss your suggested hypothesis and experimental design with others and make any refinements to improve it.

Conclusion

Write a brief conclusion, remembering to link your results with the aim.

elog-0330

INVESTIGATION 5.6

Detecting starch and glucose in leaves

Aim

To detect glucose and starch in plant leaves

Glucose can be detected with a chemically sensitive paper. The polysaccharide starch, which glucose is converted into for storage, is detected by iodine.

Materials

- iodine solution in a dropper bottle
- 1% starch solution

- white tile or blotting paper
- leaves from seedlings or plants of one type (geranium, hydrangea, lettuce, spinach or silverbeet cuttings are good)
- glucose indicator strip with colour chart
- 1% glucose solution in a dropper bottle
- mortar and pestle
- sand
- small beakers or petri dishes for testing different substances.

Method

Part A: Testing leaves for starch

1. To observe the effect of iodine solution on starch, place a few drops of starch solution on a piece of blotting paper or a white tile. Add a few drops of iodine.
2. Soften two or three leaves by dipping them with tongs into hot water for 10 seconds.
3. Repeat the test with the softened leaves. Keep one leaf aside that is not tested with iodine to compare it with the leaves that you test.
4. Record the colour observed and the presence of starch in your table.

Part B: Testing leaves for glucose

5. To observe the effect of glucose on the glucose indicator strip, place a drop of glucose solution on the end of the strip on a white tile.
6. Use the chart of colours to determine the concentration of the glucose.
7. Using the mortar and pestle, grind some fresh leaves with a little water and a sprinkle of sand.
8. Allow a strip of glucose indicator paper to soak up the liquid.
9. Record the colour and glucose concentration in your table.

Results

Use a table to record your results.

1. Part A: Record the colour observed and the presence of starch in your table.
2. Part B: Record the colour and glucose concentration in your table.

TABLE Results of investigation 5.6

Item tested	Iodine test		Glucose test	
	Colour	Starch present?	Colour	Concentration of glucose

Discussion

By referring to your table of results, answer the following questions.

1. Describe the effect of the iodine on the starch solution.
2. Describe the effect of the glucose solution on the indicator strip.
3. What do your results suggest about the way energy is stored in leaves?
4. Is the data recorded in this experiment qualitative or quantitative?
5. Why was sand added to the mixture in the mortar?
6. The sand does not affect the result on the indicator strip. How could you show this?
7. Identify the strengths of this investigation.
8. Suggest improvements to the design of this investigation.

Conclusion

Write a conclusion, remembering to link your results with the aim.

elog-0332

INVESTIGATION 5.7

Out of the light

Aim

To investigate differences in a plant's production of starch when light is removed

Materials

- pot plant that has been kept in the dark for a few days
- several strips of aluminium foil
- scissors and sticky tape
- hotplate
- 500 mL beaker of boiling water
- test tube of ethanol
- forceps
- iodine solution and dropping pipette
- Petri dish
- watchglass with a small sample of potato starch

Health and safety guidelines

Ethanol is flammable. Do not place it near an open flame.

Method

1. Fix aluminium strips to one leaf of a plant as shown in the figure. Make sure that both sides of the leaf are covered by the strip and that you do not damage the leaf.
2. Leave the plant in the light for 3 days.
3. Remove the leaf from the plant and take off the foil.
4. Remove another leaf from the plant that was not covered in aluminium foil. Dip the leaf into boiling water for 10 seconds, then place it in a test tube of ethanol.
5. Stand the test tube in the beaker of hot water and leave for 10 minutes. This treatment will remove the chlorophyll.
6. While the leaf is in the ethanol, test a small sample of potato starch on a watchglass with the iodine solution. Note any colour change.
7. Remove the leaf from the ethanol with the forceps and dip it into the hot water in the beaker again to remove any excess ethanol.
8. Place the leaf into a Petri dish and cover with iodine solution. Note any colour change and where on the leaf any such change occurred.

Make sure that the aluminium strips are secured, and that you do not damage the leaf.

Results

1. Potato starch sample: note any colour change.
2. Leaf in iodine sample: note any colour change, and the location of the change.

Discussion

1. Glucose is produced during photosynthesis and is then converted to starch and stored. Did your test show any differences in starch production between the sections of leaf exposed to the light and the sections kept in the dark?
2. Which variable has been investigated in this experiment?
3. Why was the plant kept in the dark for a few days prior to the experiment?
4. What inferences (suggested explanations) can you make from your observations?
5. What is the control in this experiment?
6. Identify the strengths of this investigation.
7. Suggest improvements to the design of this investigation.

8. Suggest a hypothesis that could be investigated using similar equipment. (You may use internet research to identify relevant problems to investigate.)
9. Share and discuss your suggested hypothesis and experimental design with others and make any suitable refinements to improve it.

Conclusion

Write a conclusion, remembering to link your results with the aim.

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5.5 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 4, 7, 9, 10, 15	Questions 2, 5, 8, 11, 14	Questions 3, 6, 12, 13, 16

Remember and understand

1. Identify the source of energy for all ecosystems on Earth. Describe this energy.
2. a. Name the green pigment that can capture light energy.
   b. Name the structure in which you would find this pigment in a plant.
3. Name the chemical produced in photosynthesis that contains chemical energy for the plant.
4. MC What the gaseous product of photosynthesis that is released into the atmosphere through the stomata of leaves?
   A. Carbon dioxide B. Chlorophyll C. Glucose D. Oxygen
5. Identify the appropriate terms to complete the photosynthesis equation.

$$\_\_\_\_\_\_ + \text{water} \xrightarrow[\text{chlorophyll}]{\text{light energy}} \text{glucose} + \_\_\_\_\_\_ + \text{water}$$

6. Fill in the blanks to complete the photosynthesis equation.

$$6\,\_\_\_\_\_\_ + 12\,\_\_\_\_\_\_ \xrightarrow[\text{light energy}]{\text{chlorophyll}} \_\_\_\_\_\_ + 6\,\_\_\_\_\_\_ + 6H_2O$$

7. The light energy captured by chlorophyll provides the energy to split water molecules into hydrogen and oxygen. True or false?

Apply and analyse

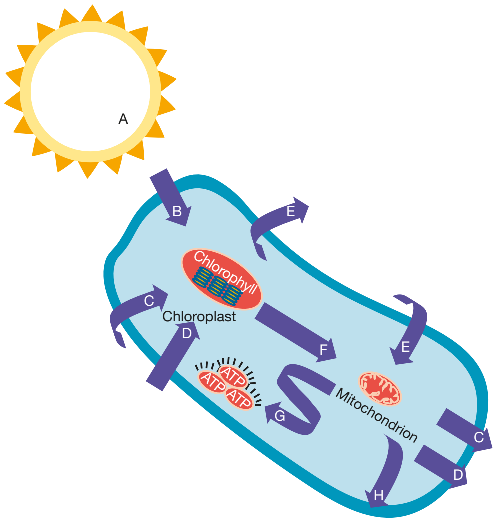
8. How can you test whether photosynthesis has occurred in all parts of a leaf?
9. Is being green essential for photosynthesis? Explain.
10. SIS If you were testing a leaf for carbon dioxide and enclosed it in a plastic bag with soda lime in it, why would you also put the control plant without soda lime (a compound that absorbs CO_2) in a plastic bag?
11. SIS Starch found in a leaf is used as evidence of photosynthesis in the leaf. Where else might the starch have come from?
12. SIS If you were measuring the effect of light intensity, why would you also need a thermometer?

Evaluate and create

13. The diagram shows a chloroplast and a mitochondrion in a plant cell.

a. Which energy conversion takes place in the chloroplast?

b. The arrows on the diagram show the flow of energy and substances into and out of the cell. Choose words from the box that are represented on the diagram by the letters A–H.



Water	Oxygen	Sun
Carbon dioxide	Heat energy	Chemical energy
Light energy	Glucose	

14. Apart from the production of food, how are plants important to life on Earth?

15. If someone said to you 'If all photosynthesis on Earth stopped, humans would eventually become extinct', would you agree or disagree? Justify your answer.

16. SIS Select one of the questions about photosynthesis in figure 5.33. Write a hypothesis and design an experiment to try and answer the question.

Fully worked solutions and sample responses are available in your digital formats.

5.6 Cellular respiration

LEARNING INTENTION

At the end of this subtopic you will be able to describe the process of cellular respiration and its importance to all organisms within an ecosystem.

5.6.1 Consumers

Unlike plants, animals cannot convert light energy into chemical energy. Our energy and nutritional demands are met by taking in or consuming other organisms. That is why we and other organisms with this need are called consumers or heterotrophs.

When a consumer eats another organism, not all of the chemical energy is used to form new tissues or stored for later use. Humans can store some of the unused energy as glycogen in their liver or as fat in fatty tissue beneath the skin. Some of the chemical energy is also converted into other forms; for example, some of it is released as heat.

5.6.2 Using, making and transforming energy

Metabolism is the use of energy by all living things. It is the conversion of chemical energy and the growth and repair of cells resulting from thousands of chemical reactions that occur in an organism — including in your body!

All living things need energy. **Cellular respiration** is the name given to a series of chemical reactions in cells that transforms the chemical energy in food into **adenosine triphosphate (ATP)** — this is a form of energy that the cells can use. The energy in ATP can later be released and used to power many different chemical reactions in the cells.

metabolism the chemical reactions occurring within an organism to maintain life

cellular respiration a series of chemical reactions in which the chemical energy in molecules such as glucose is transferred into ATP molecules, which is a form of energy that the cells can use

adenosine triphosphate (ATP) a form of energy released during cellular respiration that provides cells with the energy needed to perform their functions

Aerobic respiration is the process that involves the breaking down of glucose so that energy is released in a form that your cells can then use.

aerobic respiration the breakdown of glucose to carbon dioxide using oxygen and releasing energy in the form of ATP

The overall equation for cellular respiration is:

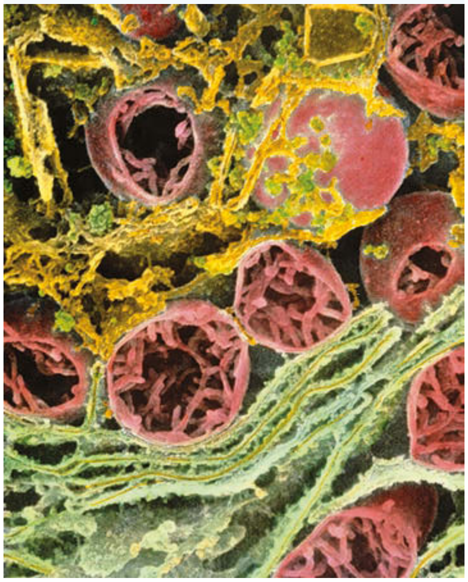
$$\text{Glucose} + \text{oxygen} \xrightarrow{\text{enzymes}} \text{carbon dioxide} + \text{water} + \text{energy}$$

$$C_2H_{12}O_6 + 6O_2 \xrightarrow{\text{enzymes}} 6CO_2 + 6H_2O + 36\text{–}38\ \text{ATP}$$

Your digestive and circulatory systems provide your cells with the glucose that is required for this very important reaction. Your circulatory and respiratory systems also work together to supply your cells with oxygen and to remove the carbon dioxide that is produced as a waste product.

5.6.3 Three stages of aerobic respiration

FIGURE 5.34 Mitochondria (shown in red) are the powerhouses of your cells.



Aerobic respiration requires oxygen and occurs in three stages. The first stage is called **glycolysis**, occurs in the **cytosol** of the cell and does not require oxygen. The next two stages are aerobic stages and occurs in the **mitochondrion** (singular, plural = mitochondria). It is in the mitochondria that most of the energy, in the form of ATP, is produced. Cells with high energy demands contain more mitochondria than other less active cells.

5.6.4 Anaerobic respiration

Most of the time, aerobic respiration is adequate to supply enough energy to keep the cells in your body working effectively. But sometimes not all of the oxygen demands of your cells can be met.

Your muscle cells have the ability to respire for a short time without oxygen using **anaerobic respiration**. Using this reaction, glucose that has been stored in your muscle cells is converted into **lactic acid**.

While the end products of aerobic respiration are always the same, the end products of anaerobic respiration can be different, depending on the organism. Humans and other animals produce lactic acid (or **lactate**), whereas plants and yeasts produce ethanol (a simple two-carbon alcohol molecule) and carbon dioxide (figure 5.36).

Although less energy is produced in anaerobic respiration (2 ATP) than in aerobic respiration (36–38 ATP), it is produced at a faster rate. This is very helpful when a quick burst of energy is needed for a short time.

glycolysis the process (that does not require oxygen) in which glucose is broken down into simpler molecules and energy is released in the form of ATP

cytosol the fluid found inside cells

mitochondrion a small rod-shaped organelle that supplies energy to other parts of the cell

anaerobic respiration the breakdown of glucose to simpler substances, in the absence of oxygen, and release of energy as ATP

lactic acid an end product of anaerobic respiration in animals; also known as lactate

lactate *see* lactic acid

FIGURE 5.35 Anaerobic respiration can be used for short times when your body does not have enough oxygen.

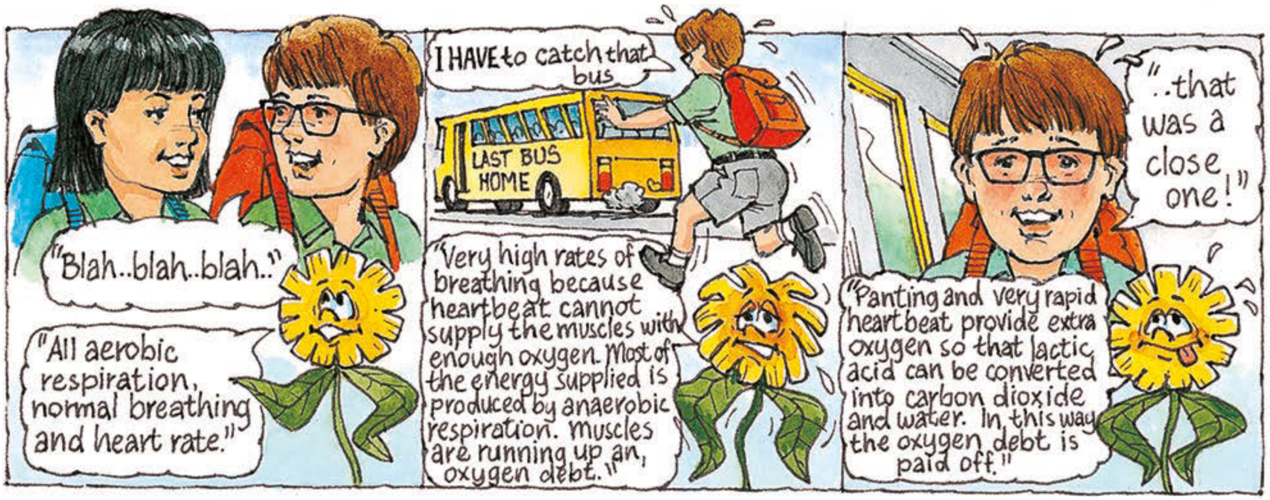
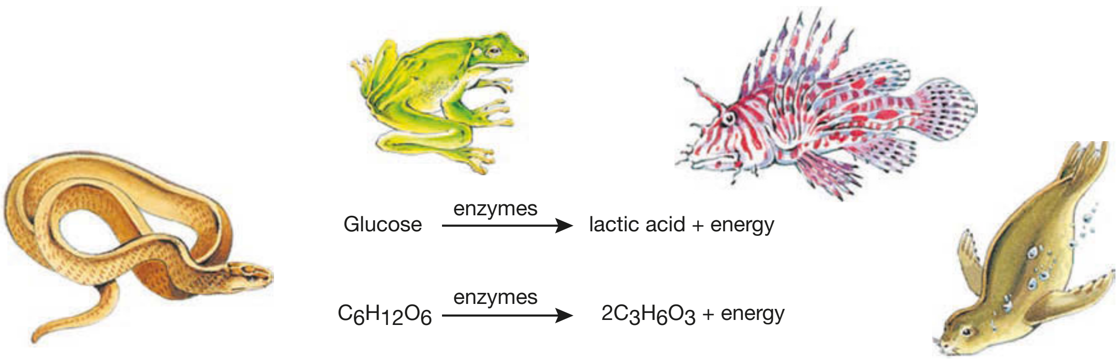


FIGURE 5.36 a. Anaerobic respiration in animals produces lactic acid. b. Anaerobic respiration in plants produces ethanol and carbon dioxide.

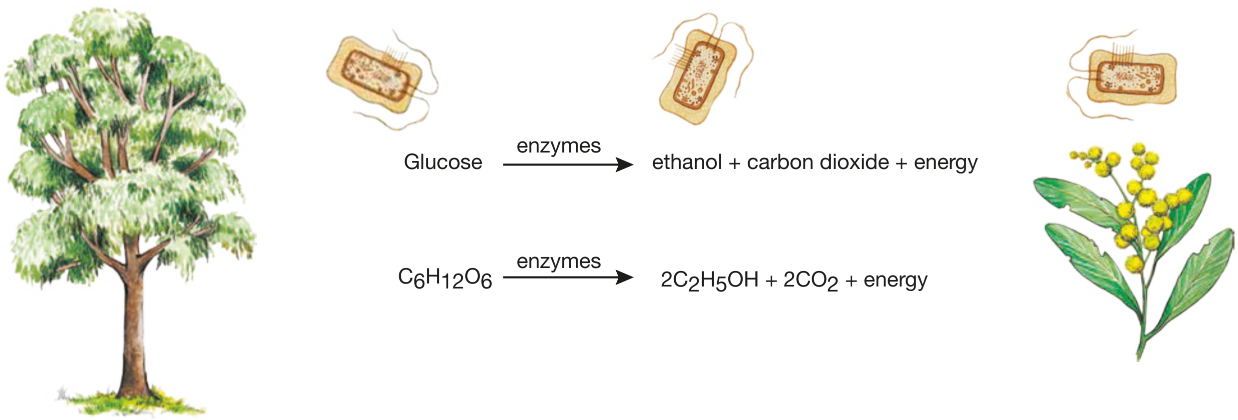
a.



$$\text{Glucose} \xrightarrow{\text{enzymes}} \text{lactic acid + energy}$$

$$C_6H_{12}O_6 \xrightarrow{\text{enzymes}} 2C_3H_6O_3 + \text{energy}$$

b.



$$\text{Glucose} \xrightarrow{\text{enzymes}} \text{ethanol + carbon dioxide + energy}$$

$$C_6H_{12}O_6 \xrightarrow{\text{enzymes}} 2C_2H_5OH + 2CO_2 + \text{energy}$$

TABLE 5.2 Features of aerobic and anaerobic respiration

Question	Aerobic respiration	Anaerobic respiration
Is oxygen required?	Yes	No
What is glucose broken down into?	Carbon dioxide + water + energy	Lactic acid + energy or ethanol + carbon dioxide + energy
For how long can the reaction occur?	Indefinitely	A short time only
Is the energy transfer efficient?	Yes	No
How fast is ATP production?	Slow	Fast
How many molecules of ATP are produced in each reaction?	36–38	2
What are the end products?	All organisms: carbon dioxide and water	Animals: lactic acid + energy Plants and yeasts: ethanol + carbon dioxide + energy
About how much energy is released per gram of glucose?	16 kJ	1 kJ

DISCUSSION

What am I?

You have to fill me with fuel regularly. The fuel is burned inside me in a chemical reaction in which chemical energy is transformed into mechanical energy. I get very hot when fuel is burned. The faster I go, the more fuel I need. I release waste products that smell and can pollute the environment.

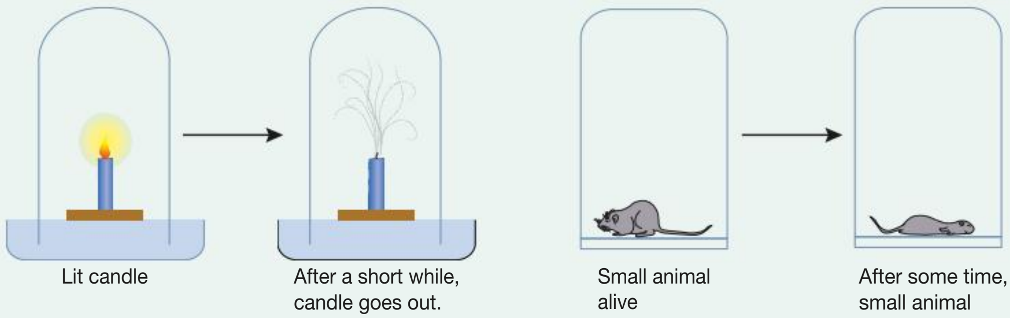
EXTENSION: Respiring without oxygen

Some micro-organisms respire only anaerobically, and can die in the presence of oxygen. These are referred to as **obligate anaerobes**. The bacterium *Clostridium tetani* is an example of an organism that can thrive only in the total absence of oxygen. At the site of a wound, tissue necrosis (death) provides a locally anaerobic environment in which these bacteria can grow. This bacterium releases toxins that cause tetanus (or lockjaw), a painful condition in which muscles remain contracted.

obligate anaerobes organisms that can respire only anaerobically (in the absence of oxygen)

How did we find out about the link between respiration and oxygen? Robert Boyle (1627–1691) performed experiments that showed that something in air was needed to keep a candle burning and an animal alive. Joseph Priestley (1733–1804) took Boyle's experiment a step further and showed that plants produced a substance that achieved this. This experiment was shown in the timeline in 5.5.4.

FIGURE 5.37 Robert Boyle's experiments on respiration and oxygen



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5.6 Exercise

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Select your pathway

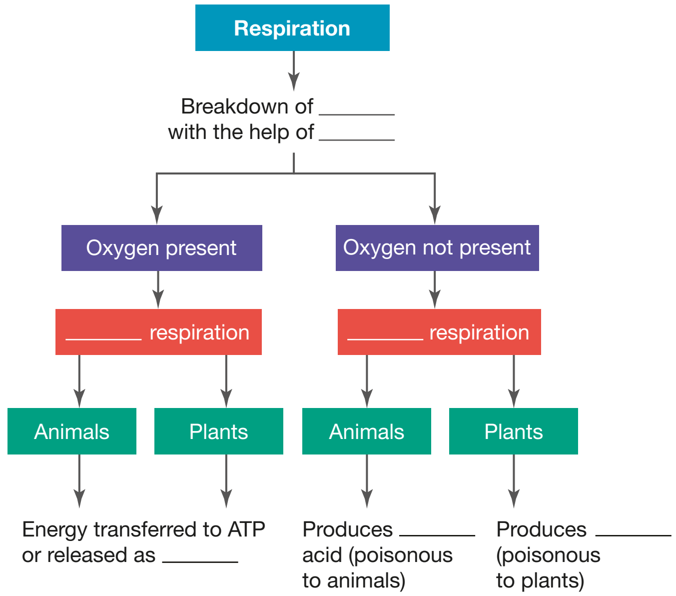
LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 3, 4, 6, 8, 13, 16	Questions 2, 5, 9, 10, 11, 15, 17, 22	Questions 7, 12, 14, 18, 19, 20, 21

Remember and understand

1. Suggest why humans are referred to as consumers or heterotrophs.
2. Define the term *metabolism.*
3. **MC** Which organisms respire?
   A. Animals only **B.** Mammals only **C.** All living organisms **D.** Plants only
4. **MC** Identify the name of the molecule that ATP is an abbreviation for:
   A. Acetyl triphosphate **B.** Adenine triphosphate
   C. Adenosine triphosphate **D.** Amino triphosphate
5. Does metabolism occur in plants?
6. Write a word equation for aerobic respiration.
7. Write the chemical equation for aerobic respiration.
8. Describe what happens to chemical energy that is stored in your body.
9. What is the purpose of aerobic respiration?
10. Outline the importance of ATP.
11. Write the word equation for anaerobic respiration in:
    a. animals **b.** plants, yeasts and bacteria.

Apply and analyse

12. Complete the flow chart to illustrate the differences between aerobic and anaerobic respiration.

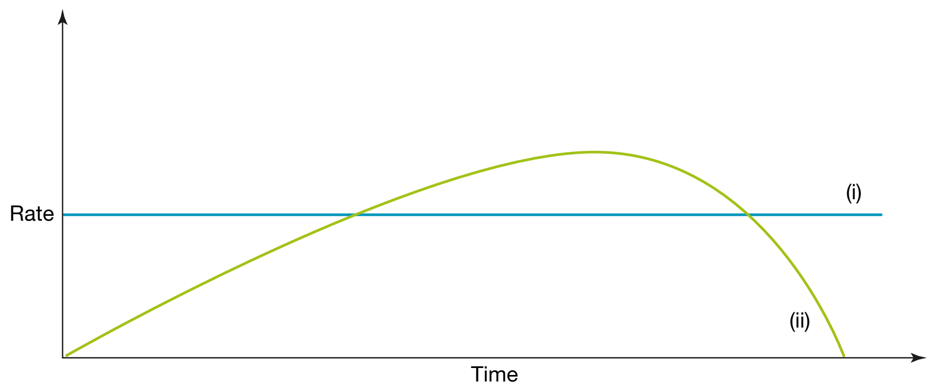


13. Use a Venn diagram to compare aerobic and anaerobic respiration.
14. a. What are the advantages of anaerobic respiration to a person who is a short-distance swimmer?
b. What are the disadvantages of anaerobic respiration to the body?
c. Which type of respiration, aerobic or anaerobic, is more likely to occur in each of the following activities?
i. Ten sit-ups
ii. A leisurely walk
iii. Lifting a very heavy steel bar above your head
iv. Watching TV from the sofa
v. A 30-metre sprint to catch the dog
15. The muscles of a sprinter respire anaerobically throughout a race.
a. Suggest how the sprinter could compete in a 100 m race without breathing.
b. Why does the sprinter need to pant to get extra oxygen at the end of the race?
c. Where does the extra oxygen enter the body while panting is used for breathing?

Evaluate and create

16. Intestinal tapeworms excrete lactic acid directly into their host's gut. Suggest the advantage to the tapeworm of this behaviour.
17. *Clostridium botulinum* is an anaerobe that cannot survive in the presence of oxygen. This microbe causes a potentially lethal form of food poisoning called botulism. Suggest why this bacterium may be a problem in canned foods.
18. Suggest why one type of cellular respiration releases more energy than the other.
19. Why is it correct to say that your body burns food?
20. **SIS** Using your knowledge of cellular respiration, suggest a link(s) between cellular respiration and the:
a. digestive system b. circulatory system c. respiratory system.
21. **SIS** Look at the graph showing the relationship between photosynthesis and respiration.
a. Which line of the graph represents the rate of photosynthesis?
b. When would the rate of respiration be greater than the rate of photosynthesis?
c. State three similarities between respiration and photosynthesis.

Rates of photosynthesis and respiration for a plant over a 24-hour period.



22. **SIS** Suggest the effect of activity and exercise on aerobic respiration.

Fully worked solutions and sample responses are available in your digital formats.

5.7 Relationships in ecosystems

LEARNING INTENTION

At the end of this subtopic you will be able to describe the relationship between the recycling of matter and the self-sustainability of ecosystems.

5.7.1 Sustainable ecosystems

Communities within ecosystems are made up of populations of different species of organisms. Interactions between these populations and their environment enable matter to be recycled and energy to flow through the ecosystem.

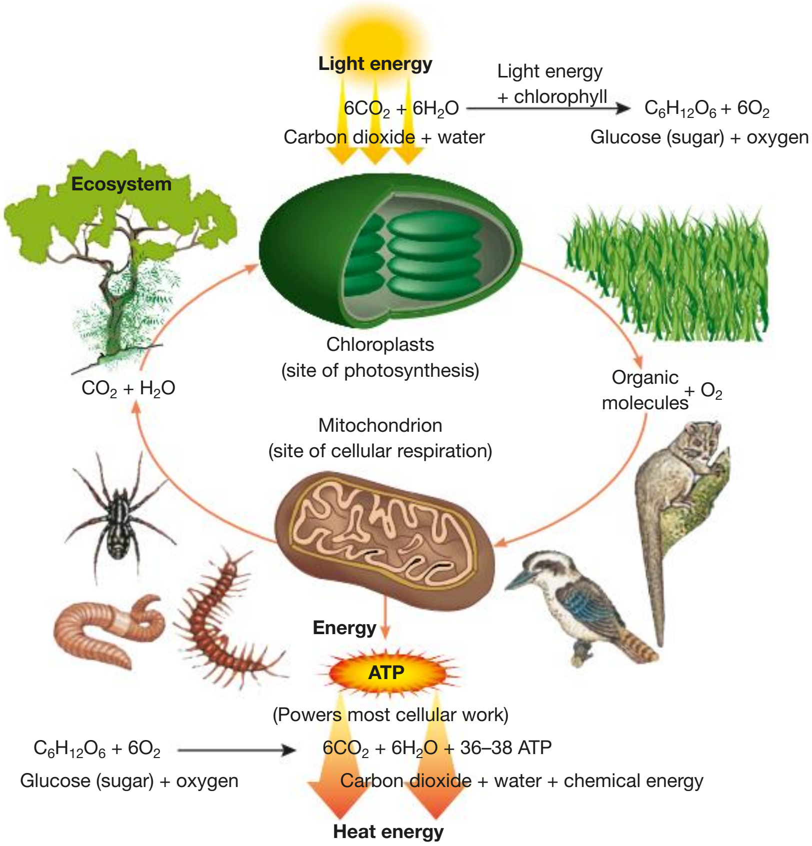
The recycling of matter through the community interacting with abiotic factors allows the ecosystem to be self-sustaining. An ecological balance allows for the survival and reproduction of all populations within the community. This means the ecosystem can continue into the future as long as it has the energy input from the Sun.

5.7.2 Energy flows through ecosystems

Light energy is captured by producers and converted into chemical energy using the process of photosynthesis. Some of this energy is used by the producers themselves, some is released into the atmosphere and some is passed on through food chains to consumers. Energy flows through ecosystems.

Cellular respiration is a process that all living organisms use to convert energy into a form that their cells can use (ATP, see subtopic 5.6). Glucose and oxygen (the products of photosynthesis) are used in cellular respiration.

FIGURE 5.38 Photosynthesis is the process involved in capturing light energy and converting it into chemical energy. Respiration is the process that uses chemical energy produced from photosynthesis for energy to live.



Living in the dark

How can ecosystems exist on the ocean floor, where there is no light for photosynthesis? Rather than being photosynthetic, some organisms are **chemosynthetic**. They use energy released from chemical reactions (rather than light) to produce organic molecules. Examples of these non-photosynthetic producers are autotrophic bacteria such as *Thiobacillus* spp.

5.7.3 Food chains and food webs

Feeding relationships in ecosystems can be described as **food chains** and **food webs**. Food chains show the direction of the flow of energy. Interconnecting or linked food chains make up a food web.

chemosynthetic organisms that produce organic material using energy released from chemical reactions rather than light

food chains a flow chart that shows the flow of energy from one organism to another as a result of feeding relationships

food webs diagram that shows interlocking food chains within an ecosystem

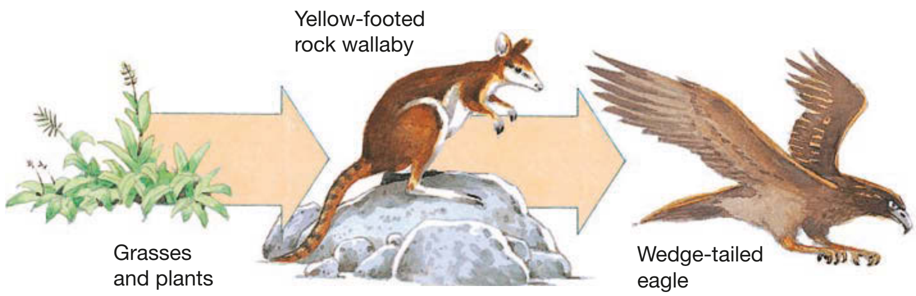
trophic level a level within a food chain, food web or food pyramid

first-order consumer an organism that is within the second trophic level of a food chain (herbivores); also known as a primary consumer

second-order consumer an organism that is within the third trophic level of a food chain (carnivores); also known as a secondary consumer

int-3462

FIGURE 5.39 A simple food chain



Trophic levels and orders

Within a food chain, each feeding level is called a **trophic level**.

Producers make up the first trophic level and herbivores the next. As herbivores are the first consumers in the food chain, they are at the second trophic level and are referred to as **first-order consumers** (also known as primary consumers). Consumers that eat the herbivores are at the third trophic level and are called **second-order consumers** (also known as secondary consumers). As only about 10 per cent of the chemical energy is passed from one trophic level to the next, most food chains do not usually contain more than four trophic levels.

Some examples of organisms that could be present at each level are in figure 5.40. Organisms can appear within more than one trophic level.

int-3464

FIGURE 5.40 Trophic levels of food chains

First trophic level	Second trophic level	Third trophic level	Fourth trophic level
Producer	**Primary consumer**	**Secondary consumer**	**Tertiary consumer**
For example: grass, phytoplankton, trees	For example: rabbits, zooplankton, wallabies	For example: starfish, eagles, owls	For example: sharks, snakes

5.7.4 Matter cycles through ecosystems

Food chains and food webs also describe how matter can be recycled through an ecosystem. Carefully observe each of the following figures to see how these relationships assist in maintaining a sustainable ecosystem.

FIGURE 5.41 A simplified view of how matter is cycled within an ecosystem

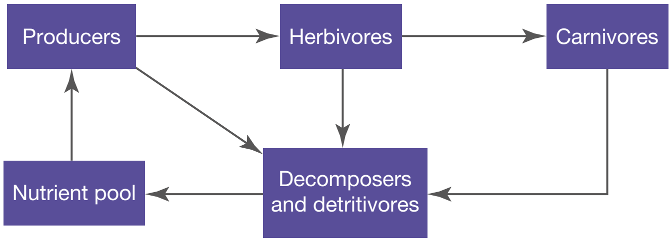


FIGURE 5.42 A simplified view of how carbon is cycled within an ecosystem

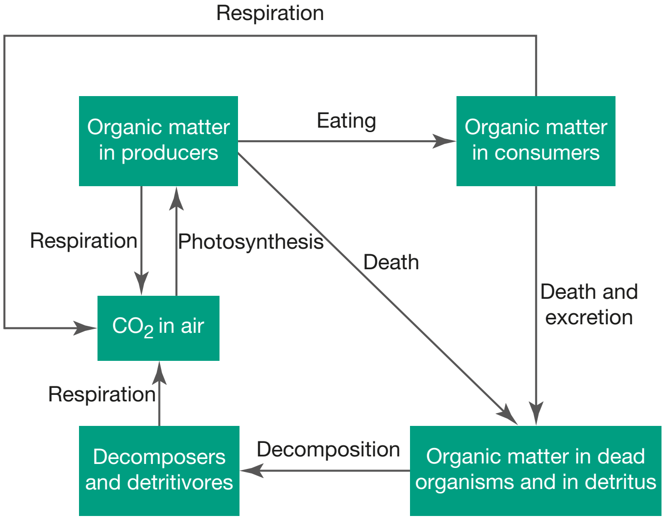


FIGURE 5.43 A simplified view of how nitrogen is cycled within an ecosystem

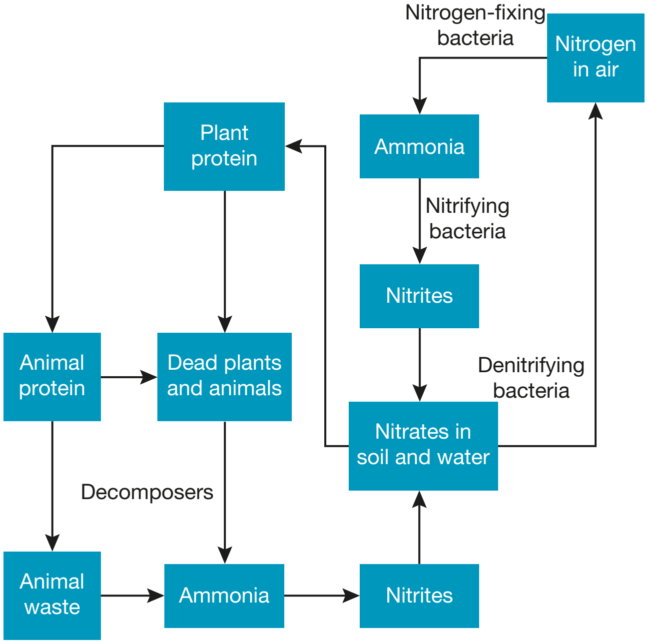
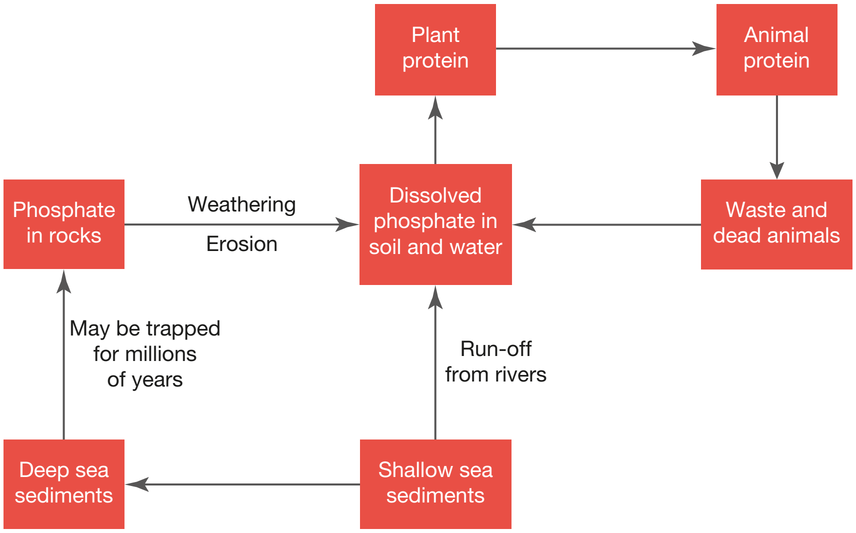


FIGURE 5.44 A simplified view of how phosphorus is cycled within an ecosystem



5.7.5 Ecological pyramids

Ecological pyramids can provide a model that can be used to describe various aspects of an ecosystem. They can show the:

- flow of energy
- recycling of matter through an ecosystem
- number of organisms and relationships between them.

These pyramids are constructed by stacking boxes that represent feeding (or trophic) levels within a particular ecosystem. The size of the box indicates the number or amount of the feature being considered.

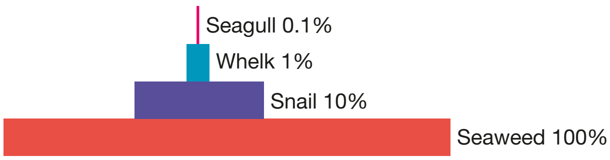
Energy pyramids

An **energy pyramid** for a food chain as described below would show a larger box at the bottom and smaller boxes as you move up the food chain. Energy pyramids always have this basic shape, because only some of the energy captured by producers is converted into chemical energy. Of the energy captured, only about 10 per cent is passed on through each feeding level, with about 90 per cent of the energy being transferred to the environment as heat or waste (see figure 5.45).

energy pyramid a representation of the level of food energy at each level within a food chain

This decrease in energy along the food chain is one reason that the numbers of levels in food chains are limited. There is also a limit to the number of organisms that can exist at each level of the food chain. Energy pyramids show that, as you move up the food chain or web, there is less food energy to go around and therefore fewer of each type of organism.

FIGURE 5.45 An energy pyramid — only about 10 per cent of the food energy received at each level is passed through to the next; the other 90 per cent is transferred to the environment.



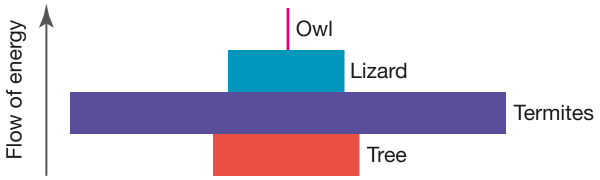
Pyramids of numbers and biomass

A **pyramid of numbers**, as the name suggests, indicates the population or numbers of organisms at each trophic level in the food chain. A **pyramid of biomass** shows the dry mass of the organisms at each trophic level. These pyramids can appear as different shapes due to reproduction rates or mass differences between the organisms.

pyramid of numbers a representation of the population, or numbers of organisms, at each level within a food chain

pyramid of biomass a representation of the dry mass of organisms at each level within a food chain

FIGURE 5.46 A pyramid of biomass shows the dry mass of the organisms at each trophic level.



on Resources

eWorkbook Cycling of materials (ewbk-3908)

assess on Additional automatically marked question sets

5.7 Exercise

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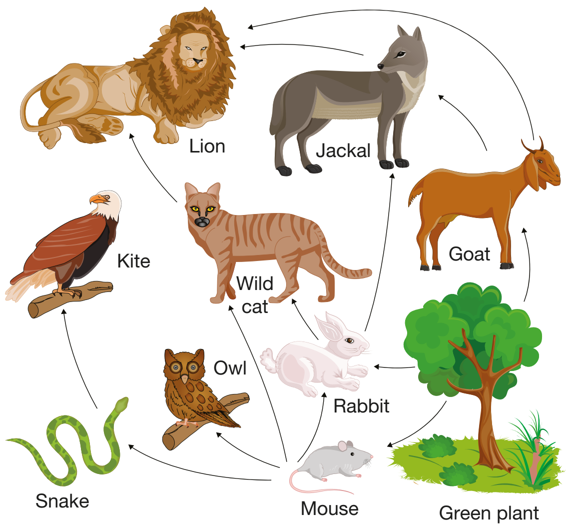
Select your pathway

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

Remember and understand

1. Rank these terms in order of complexity:
   - ecosystem
   - population
   - community
2. MC Identify the term used to describe each feeding level within a food chain?
   A. Food web
   B. Pyramid of biomass
   C. Pyramid of numbers
   D. Trophic level
3. MC Which of the following terms is used to describe organisms that use energy released from chemical reactions rather than light to produce organic molecules?
   A. Bactosynthetic
   B. Chemosynthetic
   C. Heterosynthetic
   D. Photosynthetic

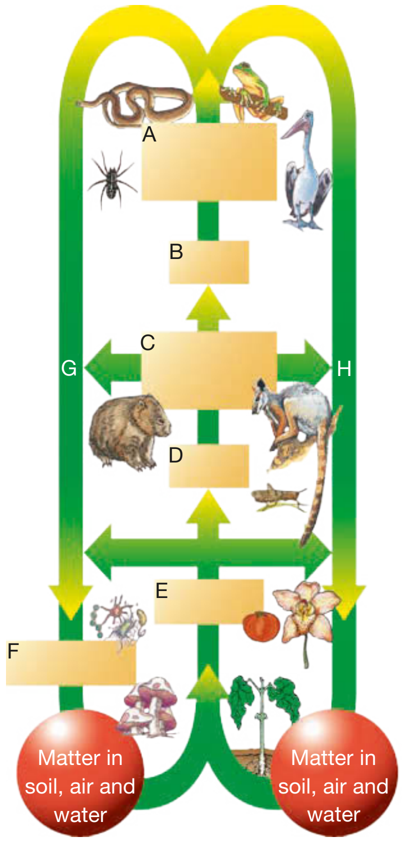
4. MC The image is an example of which one of the following?
   A. Food chain
   B. Food web
   C. Pyramid of biomass
   D. Trophic level
5. MC Identify which type of ecological pyramid indicates that, as you move up the food chain, there is only about 10 per cent of the food energy received at each level, which is passed through to the next.
   A. Energy pyramid
   B. Pyramid of biomass
   C. Pyramid of numbers
   D. Pyramid of weight
6. For the following groups of organisms, identify which tropic level they belong to.
   a. Producer
   b. Secondary consumer
   c. Primary consumer
   d. Tertiary consumer



7. Apply your knowledge of ecosystems to complete the following sentence.
   Interactions between populations and their environment enable matter to __________ and energy to _________ through the ecosystem.

Apply and analyse

8. Suggest why food chains rarely contain more than four trophic levels.
9. Label the flow chart with the following:
   producers, decomposers, second-order consumer, eaten, first-order consumer, eaten, death and wastes, respiration



10. Complete the following table.

Trophic level	Organism	Food source
First		Convert inorganic substances into organic matter using sunlight energy and the process of photosynthesis
	Primary consumer (herbivore)	Plants or other producers
Third		
	Tertiary consumer (carnivore)	

Evaluate and create

11. Construct a food chain that contains these four organisms: quail, grass, owl, lion. Identify the tropic level each belongs to.

Fully worked solutions and sample responses are available in your digital formats.

5.8 Changes in populations

LEARNING INTENTION

At the end of this subtopic you will be able to provide examples of factors that influence population numbers, such as available resources, predators, disease, carrying capacity, introduced species and human activities.

5.8.1 Population growth

The rate at which a population can grow is determined by its **birth rate** minus its **death rate**. The size of the population is also influenced by **immigration** (the number of individuals moving into an area) and **emigration** (the number of individuals leaving an area). It is also influenced by available resources, predators and disease.

birth rate the number of organisms within a population that are born within a particular period of time

death rate the number of organisms within a population that die within a particular period of time

immigration the number of individuals moving into an area

emigration the number of individuals leaving an area

The overall growth rate can be calculated by the formula:

$$\text{population growth} = (\text{births} + \text{immigration}) - (\text{deaths} + \text{emigration})$$

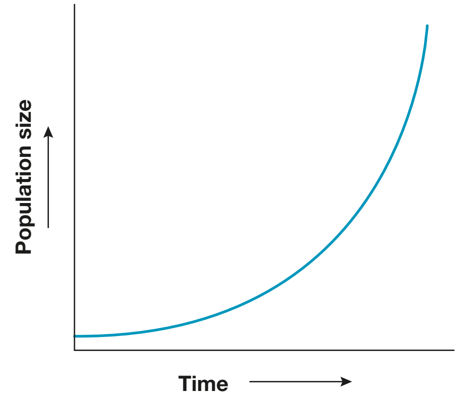
on Resources

Video eLesson Reducing your carbon footprint (eles-0163)

5.8.2 Growth without limits

If you were to provide a population with plenty of food and lack of predators and disease, it would grow rapidly. A bacterium, for example, divides every 20 minutes. Under favourable conditions, that single bacterium would produce a population of over 1 million individuals within 7 hours! Graphing this population growth would result in a J-shaped growth pattern known as **exponential growth** (figure 5.47).

FIGURE 5.47 Exponential growth in population



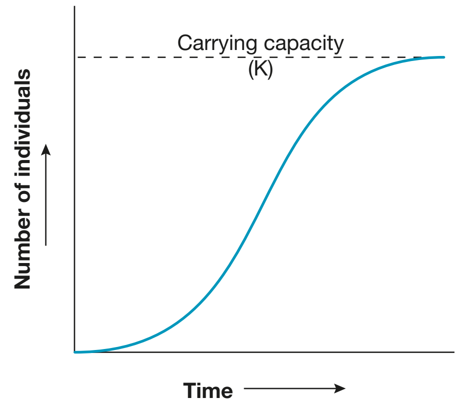
5.8.3 Carrying capacity

In the example of bacterial growth in 5.8.2, exponential growth was acheived due to an abundance of food and lack of predators and disease. Most populations do not show exponential growth. Instead, populations have only a limited amount of resources and if you were to graph their growth it would look more like an S-shaped, or **sigmoid**, graph. When the graph reaches the horizontal the population growth is zero (overall). This is described as having reached a **steady state phase**, **plateau phase** or equilibrium.

This can be achieved when:

- the birth and death rates balance each other out; a point of **zero population growth** is reached if there is no net immigration (into) or emigration (out of) a population
- a population in its plateau phase may have reached its **carrying capacity** — the maximum population size of a species in that ecosystem. Below that number the population increases as shown in the graph and above that number the population decreases due to shortages of food or other resources.

FIGURE 5.48 Population reaching carrying capacity



exponential growth a rapid increase in number or size, represented by a J-shaped graph

sigmoid the shape of a graph that shows a population increasing in number then reaching a plateau

steady state phase *see* plateau phase

plateau phase a state in which conditions are balanced and there is neither growth nor a decrease in number; also known as steady state or equilibrium

zero population growth the point at which the population does not increase in size

carrying capacity the maximum population size that a particular environment can sustain

5.8.4 Changes in populations

We can predict the effect of a change in size of a particular population on an ecosystem by observing feeding relationships in food webs. For example, if the number of the producers decreases, then herbivores will decrease in number. This means the carnivores that eat the herbivores will also be affected and each trophic level is affected by a reduction in producers. Interestingly, a change in the number of predators can also have an unexpected effect on other populations; see *Case study: The wolves of Yellowstone* that follows.

If a new species is introduced it may compete for the resources of another species, leading to a reduction in that population. This may have implications for organisms that either eat or are eaten by the affected population.

CASE STUDY: The wolves of Yellowstone

Yellowstone National Park is the oldest national park in the United States, created in 1872. In the early 1900s there were government programs to kill all the wolves in the park and the last wolf was killed in 1926. This had a number of effects:

- Elk populations increased as they had lost their key predator.
- Elk eat willow, aspen and cottonwood trees, and the increase in the elk population caused a decline in the number of these species.
- As the trees decreased in number due to overgrazing, the land started to erode and damage rivers. Overgrazing and river damage affected beaver populations.
- The coyote population increased as they had lost their main competitor.
- Increased coyotes decreased the population of antelopes in the park.

By the 1940s, there were calls to reintroduce wolves to Yellowstone to try and regain an ecological balance. But it was not until 1995 that eight wolves from Canada were introduced to the park. This had the following results:

- The elk population decreased, which resulted in reduced land degradation, and allowed river health to improve and tree species to recover.
- This allowed the beaver population to increase.
- Beavers built dams in rivers, which helped with amphibian and fish species.
- The coyote population decreased, which increased the populations of rabbits and mice.
- Increased populations of rabbits and mice lead to increased populations of hawks and badgers.

This incredible effect of removing and then introducing wolves to the ecosystem of Yellowstone National Park is why they are known as a keystone species, and demonstrates the importance of maintaining a balance in ecosystems.

FIGURE 5.49 A grey wolf feeding on elk in the Yellowstone National Park. The scavenging birds also benefit as they have an additional food source.

on Resources

Weblink How wolves changed rivers

5.8.5 Artificial ecosystems

Have you seen paddocks of cattle grazing on wheat crops? Humans have created artificial ecosystems to maximise the production of their own food supplies and resources. The purpose of agriculture is to turn as much of the Sun's light energy as possible into chemical energy, in particular crops or pasture plants for animals. In order to achieve this, humans have attempted to control populations of other organisms. This has led to interference in food webs and hence the ecosystems that contain them.

Clearing land and monocultures

To make room for crop plants, land has often been cleared of forests. The local habitats of many organisms have been destroyed. Organisms that may compete for resources or in some way potentially lower crop yields are considered to be pests and are also removed, or their populations killed or controlled.

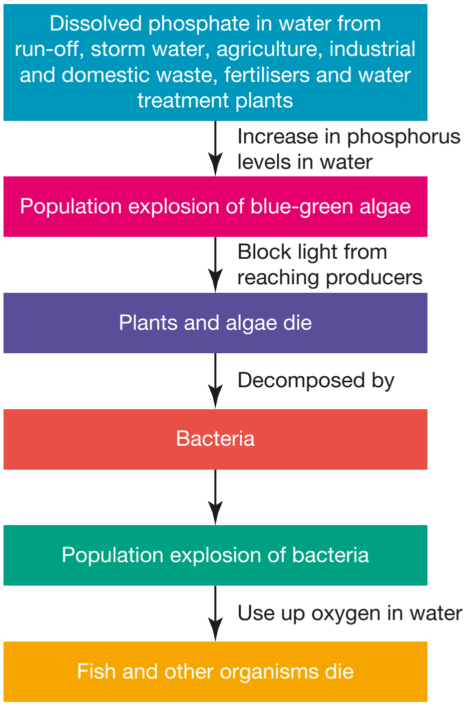
Crops are often monocultures, consisting of only one species of plant. At the end of each growing season the crops are harvested, processed and removed from the ecosystem. There is little natural decomposition of dead material, and exposed soil may be blown away by the wind. Valuable nutrients are lost from the soil. Such activities have led to the destruction of many natural ecosystems.

Effect of fertilisers

Fertilisers are added in an attempt to replace some of the lost nutrients. The main nutrients that need to be put back into the soil after the monoculture is harvested are nitrogen, phosphorus and potassium. In 5.7.4 we saw how nitrogen and phosphorus are cycled in natural ecosystems that are self-sustaining. Some of this fertiliser may end up in waterways, adding large quantities of nitrogen and phosphorus to the water. This can lead to algal blooms or **eutrophication**, which may result in the death of organisms within the ecosystem.

In figure 5.50 we can see the water run-off carries the nutrients in the fertiliser away from where it is needed and into the rivers, which can feed blue-green algae. The blue-green algae gain so many nutrients that, together with their ability to photosynthesise, they explode in number and block light from reaching the diverse producers in the waterway.

FIGURE 5.50 Eutrophication is like suffocation of a waterway and can result in the death of organisms within the ecosystem.



5.8.6 Controlling pests

Organisms that compete for resources or potentially lower the yield of the plant crop being grown are considered to be pests that need to be controlled. Pest control may be carried out using chemical or biological control.

Biological control of pests

Biological control of unwanted organisms can exploit naturally existing ecological relationships. Predators or competitors may be used to kill or reduce numbers of the pests or somehow disrupt the pests' reproductive cycle. A disease, for example, might be used to kill the unwanted organism without harming other species. While some cases of biological control have proven to be successful, others (such as the introduction in Australia of cane toads and prickly pear plants) have caused a variety of new problems.

Chemical control of pests

Chemical methods of control include the use of pesticides such as **insecticides**, **fungicides**, **herbicides** or **fumigants**. Insecticides are used to kill organisms that compete with humans for the food crops. Herbicides kill plants other than the planted crop so that they do not compete for nutrients and water in the soil, and light from the Sun.

Although pesticides are still used in agriculture, their effectiveness on target pest species often decreases. Other species may also be affected within the ecosystem and the food webs in which the target species belongs. In some cases, concentrations of non-biodegradable pesticides (such as DDT) can be magnified along the food chain by a process described as **bioaccumulation** or biological magnification.

eutrophication a form of water pollution involving an excess of nutrients such as nitrates and phosphorus, resulting in algal blooms and possible death of fish and other organisms

insecticides chemicals used to kill insects

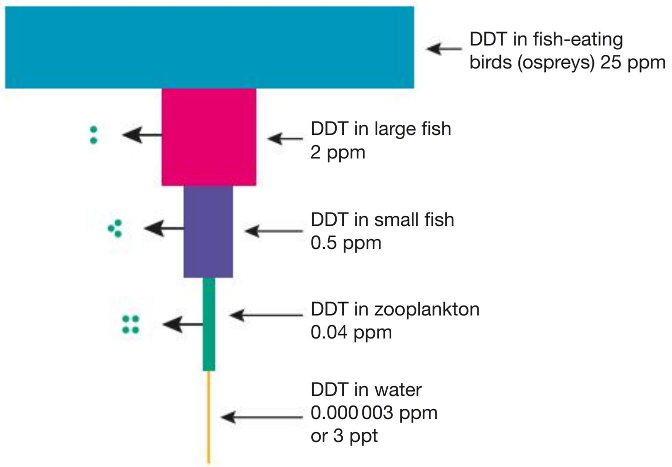
fungicides chemicals used to kill fungal growth

herbicides chemicals used to kill unwanted plants (weeds)

fumigants chemicals used in the form of smoke or fumes, to kill pests

bioaccumulation the magnification of concentrations of a substance such as a nonbiodegradable pesticide along the food chain; also known as biological magnification int-3458

FIGURE 5.51 Bioaccumulation of pesticide DDT results in increased levels up the food chain.

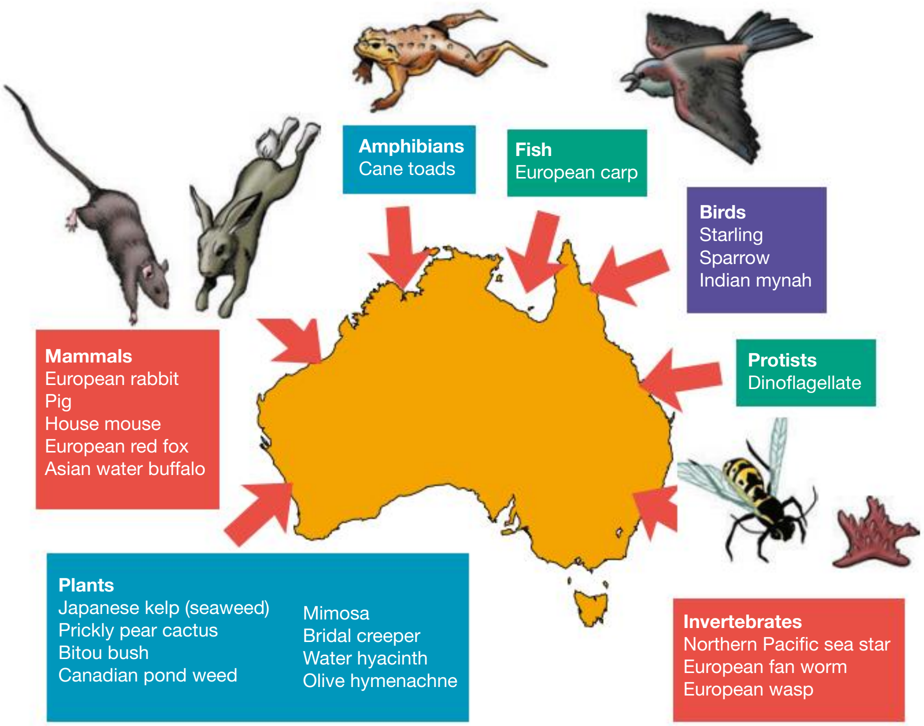


5.8.7 Introduced species

An **introduced species** is one that has been released into an ecosystem in which it does not occur naturally. The food webs in ecosystems are very delicate and can easily be unbalanced, especially when new organisms are introduced. These introduced organisms compete with other animals for food, provide predators with a new source of prey, or may act as predators themselves.

introduced species an organism that has been released into an ecosystem in which it does not occur naturally

FIGURE 5.52 Some of the many introduced species in Australia that have become pests



Cane toads

Ecological impact:

- Occupying water habitats so that native tadpoles cannot live there
- Killing fish that eat the tadpoles and other animals that eat the adult toads
- Eating our natural wildlife including frogs, small lizards, birds, fish and insects
- Poisonous; fatal to animals that eat them.

FIGURE 5.53 Cane toad

Northern pacific sea star

Ecological impact:

- Potential great harm to our marine ecosystem and to marine industries
- Threatening biodiversity and shellfish aquaculture in south-eastern Tasmania and Port Phillip Bay
- It is a voracious predator; some of our native marine species, such as scallops and abalone, don't recognise it as a predator, so do not try to escape it
- No natural predators or competitors to keep the population under control.

FIGURE 5.54 Northern pacific sea star

Rabbits

Ecological impact:

- Competing for food with the native animals such as kangaroos, wallabies, wombats and bandicoots
- Disrupting food webs and unbalancing ecosystems
- Building extensive underground warrens
- Stripping most of the vegetation in their area, causing another problem — erosion. Without plant roots to hold the soil, wind and rain carry the soil into creeks, rivers and lakes, causing further problems for the organisms that lived there.

FIGURE 5.55 Rabbits

SCIENCE AS A HUMAN ENDEAVOUR: Controlling rabbit populations using viruses

Researchers are working on an immunocontraception method that aims to block conception in rabbits to control their numbers. This method will use a virus that has been modified to contain genetic material that codes for the production of a protein essential for reproduction. When infected with this modified virus, (it is hoped that) the female rabbit produces the protein and her immune system responds by producing antibodies against it. These antibodies should then attack her eggs, blocking conception.

on Resources

Video eLesson Native rats fighting for their habitat (eles-1083)

eWorkbook Introduced pests (ewbk-3910)

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5.8 Exercise

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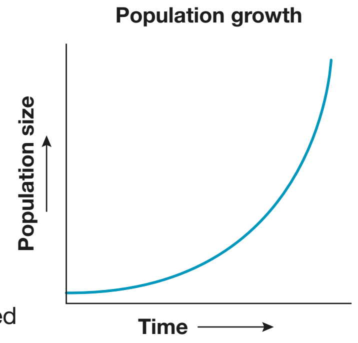
Select your pathway

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

Remember and understand

1. MC Identify the type of population growth that occurs when there is plenty of food, and lack of predators and disease, as shown in the figure.
   A. Exponential growth
   B. L-shaped graph
   C. Sigmoid growth
   D. S-shaped graph



2. What is the term used to describe the way in which concentrations of non-biodegradable pesticides (such as DDT) can be magnified along the food chain?
3. MC Identify the term used to describe a species that has been released into an ecosystem in which it does not occur naturally.
   A. Endemic species B. Extinct species C. Introduced species D. Transgenic species
4. Identify the type of pest control that exploits naturally existing ecological relationships such as predators, competitors or diseases.

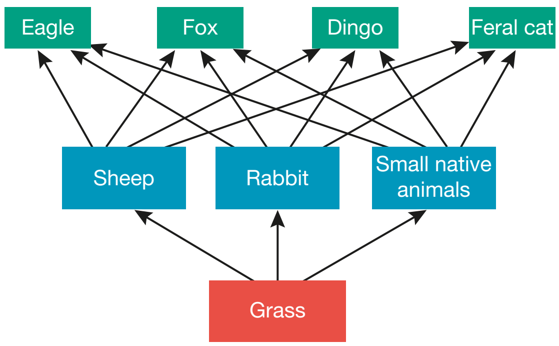
Apply and analyse

5. What is the significance of carrying capacity to population growth?
6. Match the introduced species to its ecological impact.

Introduced species	Ecological impact
a. Cane toads	A. Competes for food with kangaroos, wallabies, wombats and bandicoots and builds extensive underground warrens
b. European rabbit	B. Voracious predator of scallops and abalone and has no natural predators to keep its population under control
c. Northern Pacific sea star	C. Eats natural wildlife such as frogs, small lizards, birds, fish and insects and is poisonous to animals that eat them

Use the food web to answer questions 7–9.

7. MC Identify the most appropriate response for a possible consequence of a decrease in the population size of rabbits.
   A. Decrease in number of sheep
   B. Increase in number of small native animals
   C. Increase in population of dingoes
   D. Increase in population of foxes

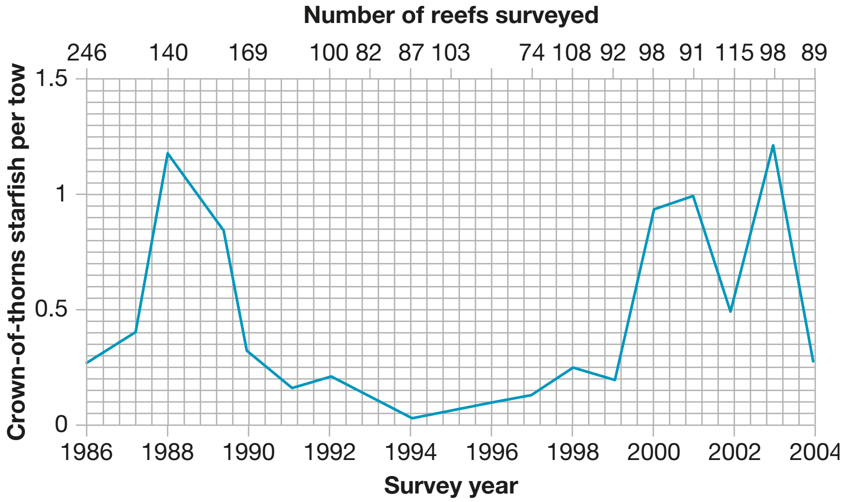


8. MC Identify the most appropriate response for a possible consequence of an increase in the population size of feral cats.
   A. Decrease in number of rabbits
   B. Increase in number of small native animals
   C. Increase in population of dingoes
   D. Increase in population of foxes

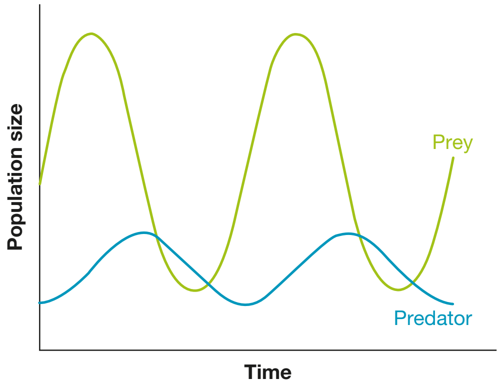
9. Suggest possible consequences of an increase in the population size of:
   a. grass   b. sheep   c. eagles.
10. List three factors that may result in:
   a. an increased population size   b. a decreased population size.
11. SIS Describe the difference between sigmoid and exponential growth patterns. What would a graph of each look like?

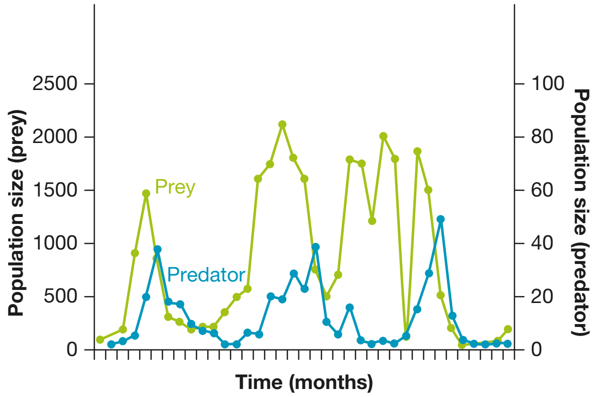
Evaluate and create

12. SIS Carefully observe the graph provided showing crown-of-thorns starfish populations recorded in Great Barrier Reef surveys between 1986 and 2004 to answer the following questions.



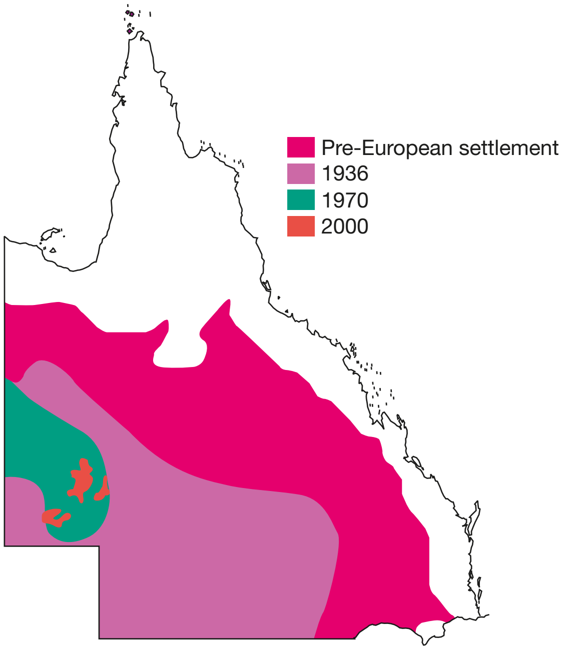
   a. MC Identify the year in which the largest number of crown-of-thorns starfish populations were surveyed.
      A. 1988   B. 1990   C. 1994   D. 2002
   b. MC Which year recorded the highest average number of crown-of-thorns starfish per tow?
      A. 1988   B. 1994   C. 2001   D. 2003
13. Carefully examine the eutrophication flow chart in figure 5.50.
   a. Suggest how dissolved phosphate in waterways can be linked to algal blooms.
   b. Do you think that suffocation is an appropriate description of the effect of eutrophication?
14. SIS Carefully observe the predator–prey graphs.
   a. Comment on any patterns observed.
   b. Suggest reasons for the observed pattern.





15. **SIS** Although populations of greater bilbies once ranged over most of mainland Australia, predation by introduced species such as cats and foxes has eliminated them from most of their former habitats.
   a. Carefully observe the figure and describe the change in bilby distribution pattern over the recorded times in Queensland.
   b. Assume there is a relationship between extent of population and size of population. From the figure, estimate the percentage population values in Queensland for each year and construct a graph to show your data.

FIGURE Queensland bilby distribution over time



Fully worked solutions and sample responses are available in your digital formats.

5.9 Adapting to dry conditions

LEARNING INTENTION

At the end of this subtopic you will be able to provide examples of adaptations of a variety of Australian plants and animals to withstand life in arid conditions.

5.9.1 Animal adaptations: dry conditions

Dry adaptations

Approximately 80 percent of Australia is described as having arid or semi-arid conditions. How can Australian plants and animals survive under such dry conditions?

Australian animals have some clever ways to cope with limited water supplies in their environments. Some of these involve putting reproduction on hold, while others produce extremely concentrated urine, and yet others possess water collection structures.

Heat adaptations

Not only is water scarce, but temperatures in our Australian outback can be very high during the day. Many Australian animals are **nocturnal** — that is, they are active only at night. Nocturnal animals have adaptations that help them find their food in the dark.

Snakes such as pythons, for example, possess heat-sensitive pits in their lower jaw that contain **thermoreceptors**, allowing the location of their warm-blooded prey to be detected (figure 5.56).

nocturnal being active only at night
thermoreceptors special cells located in your skin, part of your brain and body core that are sensitive to temperature

Bilbies are also well adapted to sense their food in the dark by using their sharp hearing and long, sensitive nose and whiskers to detect their food (figure 5.57).

FIGURE 5.56 Common name: Central carpet python. Scientific name: *Morelia bredli*

FIGURE 5.57 Common name: Greater bilby. Scientific name: *Macrotis lagotis*

CASE STUDY: How Australian animals have adapted to drought

The thorny devil

The thorny devil (*Moloch horridus)* collects dew overnight on the large spines covering its body. Moisture eventually collects in a system of tiny grooves or channels running between their scales. These channels help direct the collected water towards the lizard's mouth where a gulping action takes in the water and quenches the animal's thirst.

FIGURE 5.58 Common name: Thorny devil. Scientific name: *Moloch horridus*

Spinifex hopping mouse

The spinifex hopping mouse (*Notomys alexis*) also has a few useful tricks. These small, nocturnal animals can survive without drinking water, and produce extremely concentrated urine.
Figure 5.59 shows some ways in which they are well adapted to surviving arid conditions.

FIGURE 5.59 An outline of how *Notomys alexis*, or the spinifex hopping mouse, achieves a water balance. For survival, water inputs must balance water outputs.

5.9.2 Plant adaptations: dry conditions

Even though our native plants are unique and some have strategies to cope with our continent's harsh conditions, global warming and scarcity of water are a threat to their survival. Scientists around the world are seeking solutions to our current and future problems. One of these problems involves ways in which we can help plants survive conditions associated with droughts.

Resistant or tolerant?

Australian native plants are unique and have developed some strategies to cope with the harsh conditions that global warming and scarcity of water threaten them with. Although drought resistant and drought tolerant are often used as the same term, they are not.

- **Drought tolerant**: the plant can tolerate a period of time without water.
- **Drought resistant**: the plant can store its water and live for long periods of time without water.

Many of our Australian plants that live in water-limited environments would be classified as being drought tolerant.

drought tolerant being able to tolerate a period of time without water

drought resistant being able to store water and hence live for long periods of time without water

Drought-tolerant features

Just because a plant is an Australian native doesn't mean that it is drought tolerant. It may have evolved to be better suited to high rainfall zones or cool mountain forests. Many drought-resistant plants already grow in areas where water is scarce. Examples of drought-tolerant adaptations to look for include:

- small narrow leaves
- leaves that hang vertically
- grey or silver foliage
- furry texture
- water-retaining succulent (juicy) leaves or stems
- modified or absent leaves
- pendant branches that move with the wind to create wells in the soil under the tree, which may collect water.

FIGURE 5.60 *Grevillea* 'Robyn Gordon' is a drought-tolerant plant.

FIGURE 5.61 Eucalypt with vertical leaves and pendant branches

xerophytes plants adapted to dry conditions possessing structural and physiological adaptations for water conservation

ephemeral describes lasting for only a very short time

perennial means lasting for three or more years

5.9.3 Xerophytes

Xerophytes are plants that are adapted to survive in deserts and other dry habitats. Some xerophytes are **ephemeral** and have a very short life cycle that is completed in the brief period when water is available after rainfall. They survive periods without water by entering a state of dormancy until the next rains. This may be years later. Other xerophytes are **perennial** (living for three or more years) and rely on storage of water in specialised leaves, stems or roots.

Most cacti are xerophytes and have many structural adaptations to store rather than lose water. Their small spiny leaves reduce the amount of water lost by providing a small surface area. Their stem becomes swollen after rainfall, with pleats allowing it to expand and contract in volume quickly. The epidermis around the stem has a thick waxy cuticle and contains stomata, which usually open during the night (to collect carbon dioxide required for photosynthesis) rather than during the day when water can be lost through them.

FIGURE 5.62 Drought-resistant plants such as cacti, have developed thick, fleshy, water-storing leaves, hairy or reflective foliage and small leaves to reduce the area from which water can be lost.

SCIENCE AS A HUMAN ENDEAVOUR: Research scientist Cecilia Blomstedt

Cecilia is a research scientist at the School of Biological Sciences at Monash University. As a plant molecular biologist, she works at both the cellular and genome level of plants. Her area of research is how plants deal with abiotic stress, particularly what makes some plants more drought tolerant than others.

Cecilia works in two major areas of plant biology.

1. Desiccation tolerance in the resurrection grass, *Sporobolus stapfianus*

When most plants experience severe desiccation, only the pollen and seeds are able to survive. However, resurrection plants are able to survive extreme levels of water loss as the vegetative tissue is also drought tolerant. For example, *S. stapfianus,* can dehydrate to less than 3% relative water content (RWC), whilst typical crop plants wilt and die at ~60% RWC. Resurrection plants can stay in this dry state for long periods of time and rehydrate within 24 hours of watering. Cecilia's research team identified genes that produce proteins that protect cellular contents during drying.

Sporobolus stapfianus is native to arid regions of southern Africa but there are also Australian native *Sporobolus* species that are desiccation tolerant.

FIGURE 5.63 Cecilia Blomstedt in her laboratory at Monash University

2. Cyanogenesis and nitrogen metabolism in sorghum, including wild sorghum, native to Australia.

Sorghum is an important cereal crop used for food, fodder and biodiesel. The domesticated species, *Sorghum bicolor*, is the fifth most important crop globally; it has a high-water use efficiency and grows well in arid and semi-arid regions. One disadvantage is that sorghum produces prussic acid that can reach toxic levels under drought stress making the crop unsafe for fodder or food, resulting in substantial financial losses. Cecilia's research team generated a completely non-toxic sorghum variety. While this has advantages for agriculture it also allowed the molecular study of why plants produce certain toxins (cyanogenic glucosides). Initially it was thought to be for defence against insects, but it is now apparent that they have roles in nitrogen metabolism and turnover and in reducing oxidative stress.

Australia has 13 endemic sorghum species, growing predominantly across northern Australia (WA, NT and QLD) and Cecilia's team are currently sequencing the genomesof a subset of these species to investigate how they cope with arid, low nutrient soils in the hope of identifying traits that can be bred into domesticated sorghum. In the future, these may be used as crops well suited for Australian conditions, especially considering future climate change. One species, *Sorghum leiocladum* was extensively cultivated by Indigenous Australian peoples.

on Resources

assesson Additional automatically marked question sets

5.9 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. MC Identify the term used for plants that are adapted to survive in deserts and other dry habitats.
   A. Xerophytes **B.** Nosophytes **C.** Ephemeral **D.** Perennial
2. Identify the receptors that snakes such as pythons may use to detect the location of warm-blooded prey.
3. MC Identify the term used to describe a plant that can tolerate a period of time without water.
   A. Drought resistant **B.** Drought tolerant **C.** Ephemeral **D.** Perennial
4. Identify the common names of the following organisms:
   Moloch horridus, Notomys alexis, Macrotis lagotis, Morelia bredli
5. To cope with limited water supplies in the environments in which it lives, the spinifex hopping mouse constantly drinks and produces copious amounts of dilute urine. True or false? Justify your response.
6. Define the term *xerophyte*.
7. Outline the difference between drought resistant and drought tolerant.

Apply and analyse

8. Describe two ways in which Australian organisms can increase their chances of survival in arid or semi-arid environments.
9. Name three adaptations of Australian plants to arid environments.
10. Describe ways in which xerophytes can increase their chances of survival.
11. List adaptations that suggest a plant may be drought tolerant.

Evaluate and create

12. Evaluate the following information to determine whether the Agapanthus is drought tolerant or resistant.
    The Agapanthus is a hardy species with large roots that can efficiently store water for long periods of time. It has a long stem and clusters of tubular flowers.
13. Identify an example of a plant and an animal that live in an arid or semi-arid Australian environment. Describe their life cycle and their adaptations to survival in dry climates.
14. SIS Investigate how models can be used to predict changes to kangaroo populations due to drought. How and why are kangaroo populations measured in Australia? You may choose to show the relationship between population size and drought occurrence as a graphical model.

Fully worked solutions and sample responses are available in your digital formats.

5.10 Bushfires change ecosystems

LEARNING INTENTION

At the end of this subtopic you will be aware that communities in Australian ecosystems are impacted by bushfires and how the devastating bushfires of recent years, including 2020, have changed the populations.

5.10.1 Fire proof?

Natural disasters are not uncommon. They happen all over the world. Extremes of droughts, fire, flood, lightning, landslides, earthquakes, tornadoes, hurricanes and tsunamis are examples of natural disasters.

Australia experienced its worst bushfire season on record in the 2019–2020 summer. It has been estimated that:

- 18.6 million hectares was burnt
- over 5900 buildings destroyed
- at least 34 people were killed
- over 3 billion animals were killed.

This was accompanied by hazardous air pollution over large areas of the country. Multiple states of emergency were declared in New South Wales, Victoria and the Australian Capital Territory.

While their effects can be devastating to people, natural disasters can also have a great impact on ecosystems. In some situations, the species living within these ecosystems have developed strategies to survive such natural disasters.

FIGURE 5.64 Many Australian plants have adaptations to help them survive bushfires.

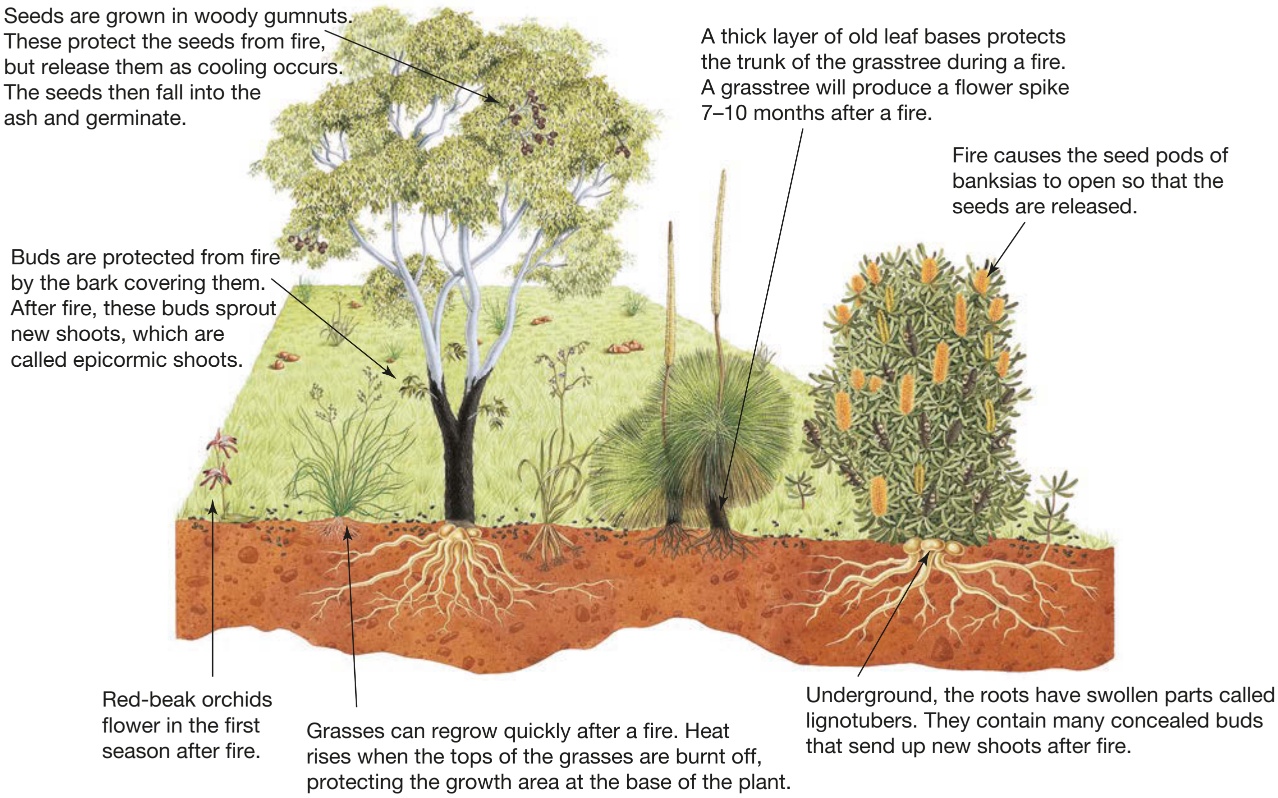
5.10.2 Bushfires

Since the last ice age, bushfires have been a natural part of Australia's unique ecosystem. Over time, this has led to natural selection of various adaptations in its inhabitants. The PMI chart in table 5.3 shows pluses, minuses and interesting points about fire and our Australian ecosystem.

TABLE 5.3 Plus, Minus, Interesting chart on Australian bushfires

Plus	Minus	Interesting
Clears the undergrowth	Slows down growth of mature trees	Aboriginal and Torres Strait Islander Peoples have traditionally used fire to manage land
Helps regeneration of plants that produce seeds in hard or waxy husks	Damages timber, reducing value of trees	Eucalypt species have many features that help them to survive bushfires
Releases stored nutrients, providing good conditions for new growth	Causes property damage if out of control	Without fire, open eucalypt forests would disappear, replaced by more dense forests containing trees that do not require fire to flower and produce seed
Makes soil structure finer and easier for seeds to grow in	Makes soil finer and more easily washed or blown away by water or wind	Some animals burrow underground to escape a fire
Destroys growth inhibitors in adult trees and allows young plants to thrive	Kills or drives off many animals, fungi and insects, and threatens other organisms in the food web with starvation	Some animals survive bushfire but die because of the reduced food supply in the period after the fire
Allows sunlight to reach the soil, helping young plants to grow	Kills decomposers, which are then lost to the life cycle	Lightning and arson cause many of the large bushfires that result in death and property damage

FIGURE 5.65 Adaptations of Australian plants in response to bushfires



Big or small?

The size of a fire has different impacts on the ecosystem. These differences are summarised in table 5.4.

TABLE 5.4 Comparison of impacts between small, controlled fires and large bushfires

Small, controlled fire	Large bushfire
Some leaf litter destroyed; many insects and decomposers survive on the ground.	All leaf litter destroyed; no insects and decomposers survive on the ground.
Soil releases stored nutrients. Ash provides many minerals and fine texture. This helps seeds to germinate and new plants to grow.	
Heat and smoke cause some plants to release seed and some seeds to germinate.	Heat and smoke cause most plants to release seed and many seeds to germinate.
Many unburnt patches where grasses and shrubs survive; animals can find food and shelter here.	Few unburnt patches; no food or shelter is left for animals.
Many animals survive and can stay in the area. Food is still available.	Many animals are killed, or must move to another habitat. No food is available.
Fallen branches and logs survive to provide shelter for animals.	No fallen branches or logs survive so there is less shelter.

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INVESTIGATION 5.8

Germinating seeds with fire

Aim

To investigate the effect of heat on germination of acacia and hakea or banksia seeds

Many seeds need fire to germinate. It could be the smoke, heat or the chemicals in ash that cause the seeds to germinate.

Materials

- hakea or banksia seed pods — unopened
- newspaper matches
- bucket of water seedling trays
- seedling mix oven
- acacia seeds (silver or black wattle work well)

Health and safety guidelines

- Make sure you are supervised by an adult.
- Burn seed pods only in a safe area.
- Do not do this activity on a hot, windy day or a day of total fire ban.
- Have a bucket of water or a fire extinguisher ready.
- Pods stay hot for some time after burning. Give them time to cool before touching them.

Method

Part A: Banksia or hakea seeds

1. Collect unopened banksia or hakea seed pods from trees in your local area.
2. Wrap the seed pods in newspaper and burn them in a safe area, over a bunsen burner or heat the pods in an oven.
3. Observe the seed pods after burning.
4. Collect the seeds and plant them in the seedling trays. Care for them until they are large enough to plant in the garden. Record the number of seeds collected and the number of seedlings observed in a table in Results. Label it Table A and give it an appropriate name.

Part B: Acacia seeds

5. Divide the acacia seeds into two equal piles. Record the number of seeds in each pile.
6. Plant one pile of seeds in a seedling tray.
7. Heat the second pile in the oven.
8. Plant these seeds in a separate seedling tray. Sprinkle some ash over the seedling tray.
9. Keep the trays moist. Wait for the seeds to germinate. This could take many days.
10. Count the number of seedlings that have germinated in each tray. Compare class results and record your results in a table. Label this Table B and give it an appropriate name.
11. Look after your seedlings and, when large enough, plant them in a garden.

Results

Part A: Banksia or hakea seeds

1. Complete the table using your results from part A.

Number of banksia/hakea seeds collected	Number of banksia/hakea seeds planted	Number of banksia/hakea seedlings after 1 week	Number of banksia/hakea seedlings after 2 weeks	Number of banksia/hakea seedlings after 3 weeks

2. Describe the seed pods after burning.

Part B: Acacia seeds

3. Complete the table using your results from part B.

	Acacia seeds without heating	Acacia seeds heated
Number planted		
Number of seedlings after 1 week		
Number of seedlings after 2 weeks		
Number of seedlings after 3 weeks		

Discussion

1. Describe the effect that heat or fire had on the pods. Refer to both table A and table B.
2. Identify which group of seeds germinated most effectively. Refer to both table A and table B.
3. Suggest what caused one group to germinate more than the other.
4. Explain how this is similar to the effect that fire would have on the seeds.
5. Suggest how opening the seed pods in response to heat may help the plants to grow at the right time.
6. Outline the strengths and limitations of this investigation, and suggest how this investigation could be improved.
7. **a.** Suggest your own investigation question about germination and fire.
   b. Design an experiment to investigate your research question.

Conclusion

Briefly describe what was learned, referring to the results.

5.10.3 Indigenous Australian land management

Indigenous Australians arrived in Australia over 65 000 years ago. They used very different hunting and gathering practices from those of Europeans and successfully managed the land. While Aboriginal and Torres Strait Islander Peoples did have significant impact on the Australian environment, their lifestyle was sustainable and allowed resources to renew.

Some of the ways in which Aboriginal and Torres Strait Islander Peoples cared for their land included:
- moving from place to place rather than staying in the same location; this ensured that the plants and animals they fed on had a chance to replenish
- eating a wide variety of food so that no single food source was depleted
- leaving enough seeds to ensure that plants could regenerate
- leaving some eggs in a nest when collecting
- not hunting young animals or the mothers of young animals
- not allowing particular members of a group to eat certain foods; this ensured that a wide variety of food was eaten and that 'taboo foods' were not depleted
- leaving the land to recover for a period of time after harvesting a crop, such as bananas; this allowed time for the crop to regenerate and nutrients to return to the soil.

Using fire

One way that early Indigenous Australian peoples affected the environment significantly was through their use of fire. Fire was used for hunting. Setting fire to grassland revealed the hiding places of goannas, and possums could be smoked out of hollows in trees. Fire was also used to clear land. The grass that grew back after the fire attracted grazing animals, which could be hunted more easily.

FIGURE 5.66 *Aborigines Hunting Kangaroos* by Joseph Lycett, circa 1817. This image of Indigenous land management and hunting was painted by Lycett when he was a convict in Newcastle, New South Wales.

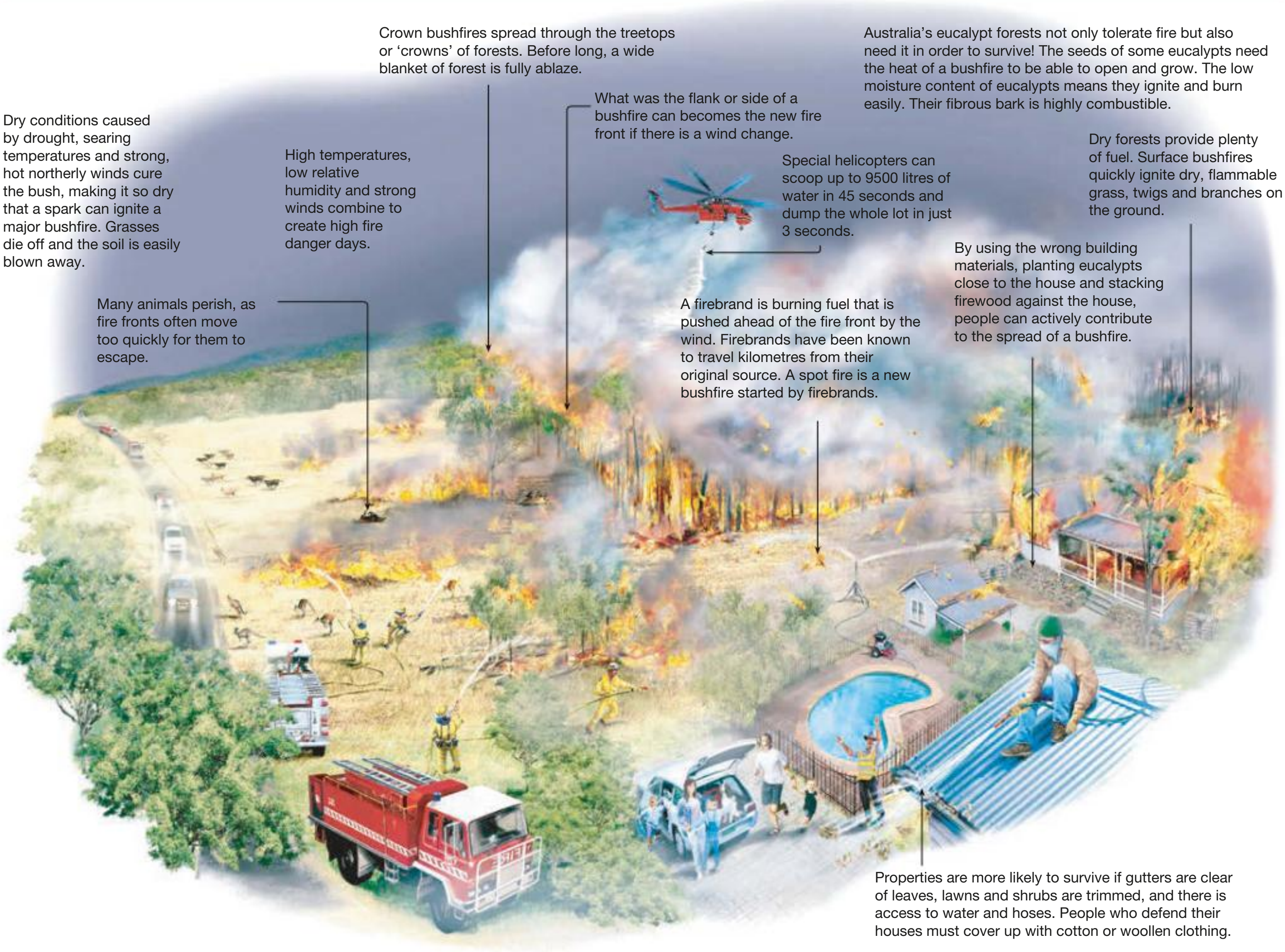
Over time, some species of plants that were sensitive to fire became extinct, whereas the plants with adaptations that allowed them to survive a fire or regenerate rapidly after a fire became more common. Adaptations are features that help an organism survive in its environment. Some modern-day species, such as the banksia, are not only well adapted to frequent bushfires; they actually need to be exposed to the high temperatures of a fire for their seeds to germinate.

5.10.4 Reducing the impact of bushfires

Large wild fires such as those that occurred in Victoria in 2009, and throughout south-eastern Australia in 2019–2020, can have devastating consequences including loss of lives and damage to property. They can also affect ecosystems. As the bush burns, animals become victims of the flames or must flee, and habitats are destroyed. One way of reducing the frequency and severity of wild fires is through regular back-burning. This involves deliberately setting fire to vegetation when temperatures are low and the winds are calm to minimise the chance of the fire spreading out of control. Controlled burning removes highly flammable vegetation that acts as fuel for bushfires.

Some of the impacts of bushfires on people and natural ecosystems are shown in figure 5.67.

FIGURE 5.67 The many effects of bushfires



DISCUSSION

Do you remember the bushfires in the summer of 2019–2020? Why do you think this fire season was so severe?

Resources

eWorkbook Amazing fire trees (ewbk-3912)

assesson Additional automatically marked question sets

5.10 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Identify one use of fire by Indigenous Australian peoples for land management.
2. Why do banksias rely on fire for their seeds to germinate?
3. Some eucalypt seeds are grown in woody gumnuts. Identify the advantages of these woody structures. How do they help the trees through fire?

Apply and analyse

4. The damage caused by bushfires in Australia is well known. Identify three advantages of small, controlled fires to Australia's ecosystems.
5. SIS In 2020 Victoria was divided into nine CFA districts. Use the website link *Find your fire district* in the resources panel of your online resources to answer the questions.
   a. Which CFA district do the following people live in?
      i. Thuy in Shepparton ii. Kyle in Mansfield iii. Penny in Swan Hill
   b. Ally lives in Omeo and her cousin Shane lives in Wangaratta. Do they live in the same CFA district?
6. Construct a Venn diagram comparing the impacts of small, controlled fires and large bushfires.
7. Watch the video *Fire and the environment* on the website link *Fire management* in the resources panel of your online resources to answer the following questions about the impact of the 2006 Grampians fire.
   a. State the program that began in the Grampians National Park after the 2006 Grampians bushfire.
   b. Which animals did not return for about 4 years after this bushfire?
   c. Could the capture–recapture method from subtopic 5.3 be used by the rangers to monitor the animals stated in part b?
   d. Which type of vegetation is burnt during winter burning in the Grampians?
   e. Describe how the site cleared in the 1960s would assist in the recovery of the Kinglake National Park after the Black Saturday bushfires in February 2009 had a devastating impact.

Evaluate and create

8. SIS The following questions are based on excerpts from the article 'These plants and animals are now flourishing as life creeps back after bushfires'. (February 2020, *theconversation.com*)

   Of course, bushfires kill innumerous trees – but many do survive. Most of us are familiar with the image of bright green sprouts shooting from the trunks and branches of trees such as eucalypts. But how do they revive so quickly?
   The secret is a protected "bud bank" which lies behind thick bark, protected from the flames. These "epicormic" buds produce leaves, which enables the tree to photosynthesise – create sugar from the sun so the tree can survive.
   Under normal conditions, hormones from shoots higher in the tree suppress these buds. But when the tree loses canopy leaves due to fire, drought or insect attack, the hormone levels drop, allowing the buds to sprout.
   This summer's fires left in their wake a mass of decaying animal carcasses, logs and tree trunks. While such a loss can be devastating for many species – particularly those that were already vulnerable – many insects thrive in these conditions.
   For example, flies lay eggs in the animal carcasses; when the maggots hatch, the rotting flesh provides an ample food source. This process helps break down the animal's body – reducing bacteria, disease and bad smells. Flies are important decomposers and their increased numbers also provide food for birds, reptiles and other species.

a. Describe how epicormic buds are a structural adaptation of eucalypts.
b. Why don't epicormic buds sprout during normal ecological conditions?
c. Name and describe the position of animals in the food web.
d. Name and describe the position of maggots in the food web. Specify how they are particularly beneficial to the ecosystem after a bushfire.

9. The following questions are based on excerpts from the article 'Yes, the Australian bush is recovering from bushfires – but it may never be the same'. (February 2020, *theconversation.com*)

> *We've all read the devastating figures of destruction this fire season. More than 11 million hectares of land burned across the country over a period of about six months.*
> *Although fires are natural in Australia, they're now occurring at an unprecedented frequency and intensity in areas that, historically, did not burn. This new regime does not allow the effective recovery of natural systems to their pre-fire state.*
> *Fires in alpine ash forests (*Eucalyptus delegatensis*) are a good example of this.*
> *Unlike many eucalypt species which can re-sprout after fire, this species' only means of recovery is through germination via a seed bank in the canopy, and rapid germination and growth of seedlings after fire.*
> *Multiple fires in quick succession kill seedlings before they reach maturity, disrupting the tree's reproductive cycle and leading to local extinction of the species in the landscape.*

a. How much land was burned across Australia during the 2019–2020 fire season?
b. Which two factors of these fires do not allow sufficient time for recovery?
c. Answer the following questions.
   i. What is the scientific species name for alpine ash?
   ii. The species name of white mountain ash is *Eucalyptus fraxinoides*. It is the closest relative of the alpine ash. They differ in their bark and seed. Use their scientific names (taxonomy) as evidence to explain how closely they are related.
   iii. How does the frequency of fires disrupt the tree's reproductive cycle and so affect the size of the alpine ash population within the community?

10. **SIS** The following questions are based on excerpts from the article 'Ash to ashes – what could the 2013 fires mean for the future of our forests?' (February 2013, *theconversation.com*)

> *Researchers from the Australian National University recently postulated that with an increase in disturbances (they looked at logging) in certain ecosystems, a "landscape trap" could arise. That is, vegetation is converted to a type which perpetuates frequent fire. The forests' environmental services – such as water, carbon and habitat – are severely compromised or at least heavily modified. Applied to the example here, we can argue that at least 6,000 ha of Alpine Ash forest is likely to be converted to shrublands or potentially even grasslands, unless the area is actively replanted. The role of forests in sequestering carbon has received much attention over the past few years. Highly productive ecosystems such as Alpine Ash are gradually being recognised for the role that they play in storing carbon dioxide.*
> *There is a reasonable degree of variation in how much they're estimated to store in above-ground carbon – anywhere from 197 to 339 tonnes of carbon per hectare, though much higher has been estimated. Shrublands, in contrast, have been estimated to store significantly less – around 60 tonnes of carbon per hectare.*
> *Therefore, if that 6,000 hectares are converted from highly productive forest to shrublands, we will see a transition from a forest that could cumulatively store anywhere between 4.3 and 7.4 million tonnes of CO_2 at maturity to shrublands that would store only a fraction of that (1.3 million tonnes of CO_2).*

a. Describe what could happen to the community of Alpine ash forest if the frequency of bushfires increases.
b. Name and describe the process by which trees sequester carbon from the air.
c. How do bushfires contribute to an increase in CO_2?
d. Draw a column graph comparing the maximum amount of CO_2 sequestered by 6000 hectares of alpine ash compared with the amount of CO_2 sequestered by 6000 hectares of shrublands.

Fully worked solutions and sample responses are available in your digital formats.

on Resources

Weblinks Find your fire district
Fire management

5.11 Thinking tools — SWOT analysis

5.11.1 Tell me

What is a SWOT analysis?

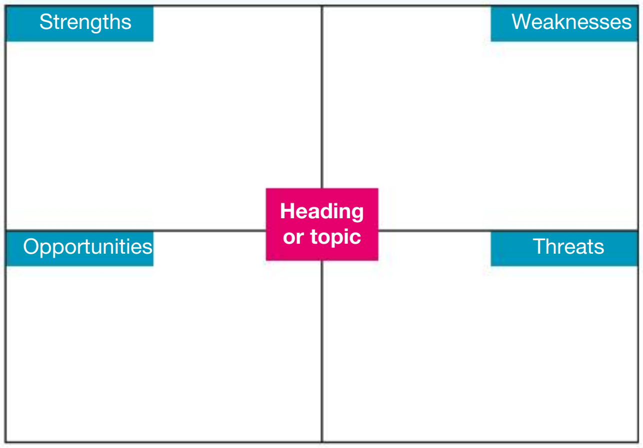
A SWOT analysis allows you to consider the following features about an issue:

- **S**trengths
- **W**eaknesses
- **O**pportunites
- **T**hreats.

They are useful to help you:

- prepare an argument or an opinion to an idea, or
- to prepare a plan of action for a project and help understand possible blockers to this plan of action.

FIGURE 5.68 SWOT analysis



5.11.2 Show me

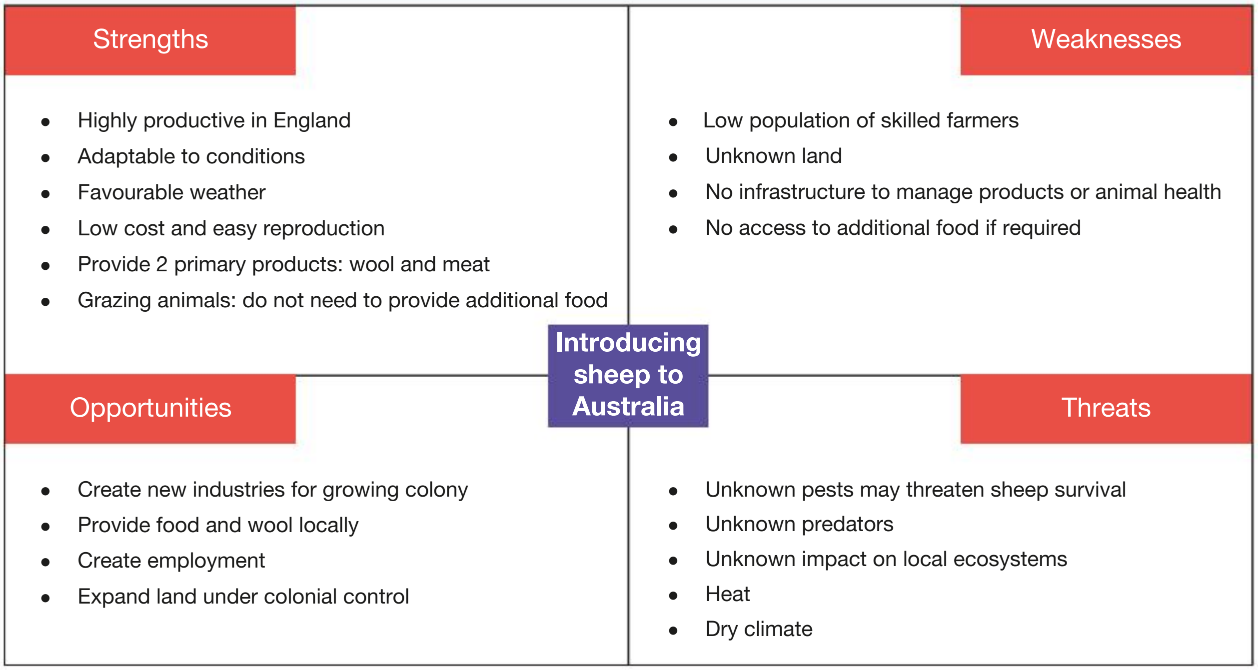
How to create a SWOT analysis

Sheep are one of the most common introduced species to Australia.

Imagine it is 1788 and you have just arrived from England to make a new life in the colony of New South Wales. You are considering introducing sheep to the new colony, but this is a risky venture. You decide to undertake a SWOT analysis of importing sheep to the new colony.

1. Draw up a square and divide it into four quarters. In the centre of the diagram write down the topic or issue that you are going to analyse (Introducing sheep to Australia).
2. Think about or brainstorm:
   a. the positive features and behaviours and record them in the Strengths section
   b. the negative features and behaviours and record them in the Weaknesses section
   c. possible opportunities and record them in the Opportunities section
   d. possible threats and record them in the Threats section.

FIGURE 5.69 SWOT analysis of introducing sheep to Australia



5.11.3 Let me do it

5.11 ACTIVITIES

1. Examine the maps showing the occurrence of bushfires and incidence of drought in Australia.

FIGURE 5.70 Drought incidence in Australia

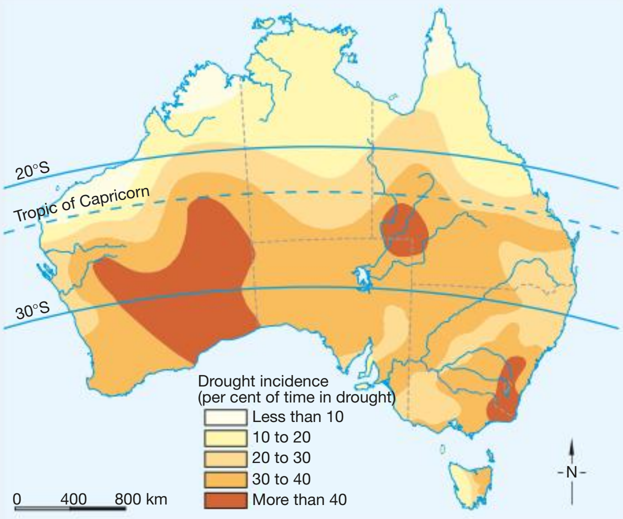
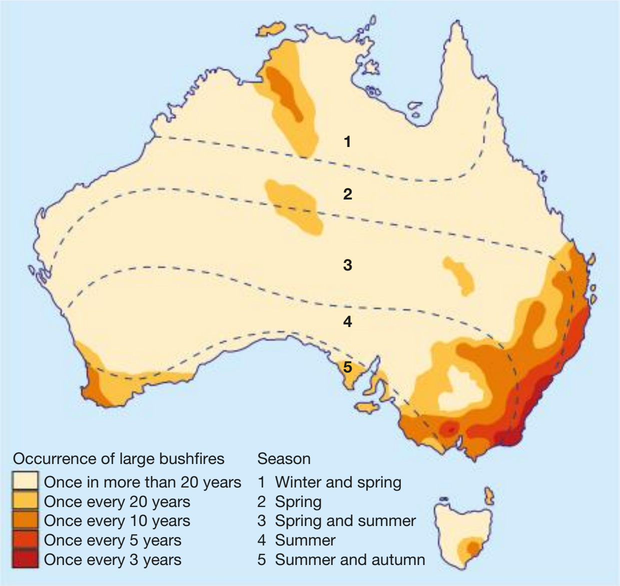


FIGURE 5.71 Occurrence of large bushfires in Australia



a. Describe patterns in the occurrence of bushfires.
b. Suggest reasons for the observed bushfire pattern.
c. Research possible causes and consequences of bushfires in Australian ecosystems.
d. Construct an overall SWOT analysis on the consequences of bushfires to populations within Australian ecosystems.
e. Describe patterns in the incidence of drought.
f. Suggest reasons for the observed drought incidence pattern.
g. Research possible causes and consequences of drought in Australian ecosystems.
h. Construct an overall SWOT analysis on the consequences of drought to populations within Australian ecosystems.

2. Examine the maps showing 2019 Australian mean temperatures compared to historical averages and 2019 Australian mean rainfall compared to historical averages.
Further information can be found in the weblink of the resources panel in your online resources.

FIGURE 5.72 2019 annual mean temperatures compared to historical temperature observations

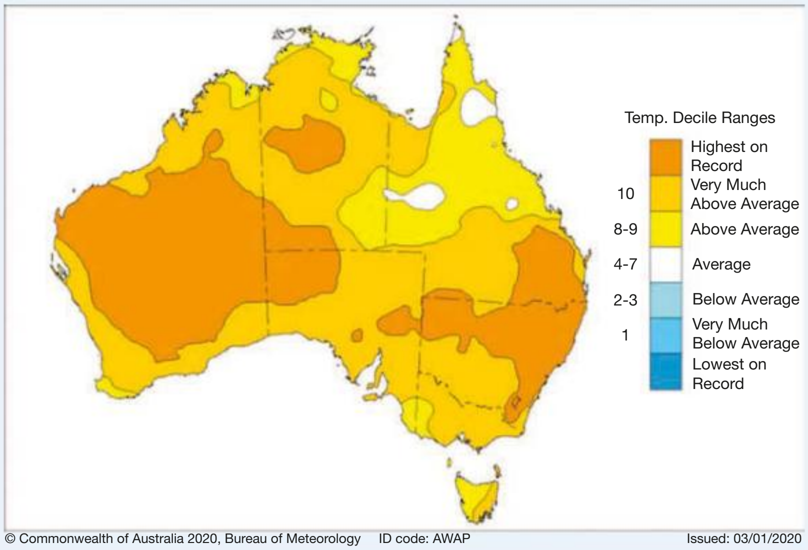
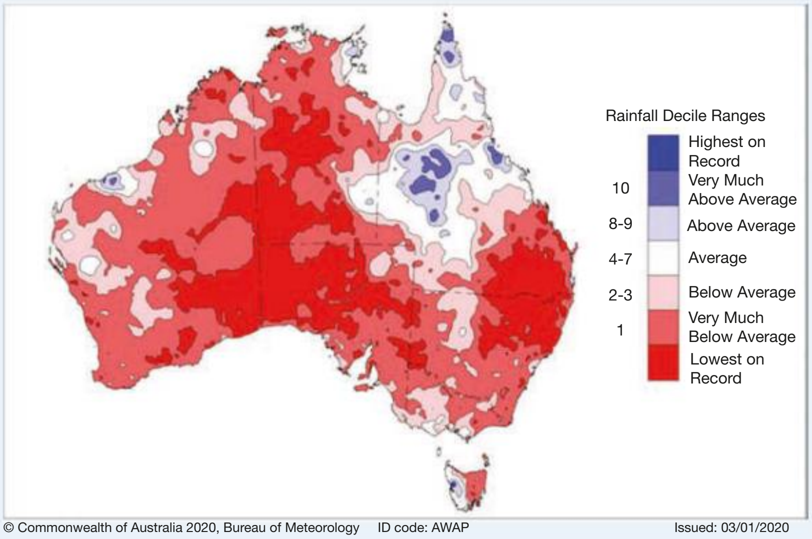


FIGURE 5.73 2019 annual rainfall compared to historical rainfall observations.



a. Select an area of Australia and research possible consequences of these highlights to populations living within ecosystems in that area.
b. Construct a SWOT analysis on the consequences of the 2019 data given on your chosen area.

Fully worked solutions and sample responses are available in your digital formats.

Resources

Weblink BOM Annual climate statement

5.12 Project — Blast off!

Scenario

By 2050, there will be 10 billion people on our small world and the human population will have expanded far beyond a number that the Earth's resources are capable of supporting. If we are to survive into the next century, we will need to find other worlds for settlement and resources. Exoplanets are planets that are found orbiting stars far from our own. So far, 560 exoplanets have been discovered, some of which could be similar enough to Earth for us to colonise. Of course, these star systems are very far away and the people who travel out into space to set up the new colonies will be on board their spaceships for very long periods of time.

The Australian Space Exploration Agency (ASEA) has been formed with the specific aim of sending a crew of 80 colonists to the exoplanet XY2305 — a world that is very similar to Earth — to form the basis of a much larger future settlement. The spacecraft engines that are presently available to the Agency are capable of getting the colonists there with a total journey time of twenty years. As part of the spacecraft design team at the ASEA, you will need to design a spacecraft that will meet all of the survival needs of the crew during their long journey.

The design brief for the spacecraft has the following specifications:

- As the spacecraft will be built in Earth's orbit and will not need to land on the planet at the other end, it does not have to have an aerodynamic shape. It can also be as large as you need; however, keep in mind that the best use should be made of the interior space so that it is easily negotiated by the colonists.
- Apart from an initial intake of supplies, all food, water and oxygen for the journey will need to be grown, recycled or produced on board the ship itself.
- If the ship is to have artificial gravity, the design must include a method of generating this gravitational field.
- Facilities need to be provided for research, sleeping, recreation and exercise.
- There will be equal numbers of male and female colonists who will be aged between 20 and 30 years of age.

Full details of the project can be found in the ProjectsPLUS link in the Resources panel of your online resources.

Your task

Your group has been given a project brief to design a spacecraft that will be able to provide life support for 80 colonists for their twenty-year journey to the exoplanet XY2305. You will present your final design to the Administration of the ASEA in the form of a PowerPoint demonstration. You may wish to include a labelled model of your spacecraft.

In your presentation, you will need to consider, among other things:

- the types of activities that an average crew member would be involved in and for how long, in each normal 24-hour period of time onboard the spaceship
- the amount of food, water and oxygen that each person will need every day to perform these activities
- how carbon dioxide would be converted into oxygen
- how water will be produced/recycled
- the different types of waste that will be produced and how these wastes will be managed /recycled.

on Resources

ProjectsPLUS Blast off! (proj-0106)

5.13 Review

Access your topic review eWorkbooks

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-3919	ewbk-3921	ewbk-3923

on Resources

5.13.1 Summary

Ecosystems

- Populations are groups of organisms of the same species living together.
- A community is many different populations living together.
- Ecosystems occur when communities of organisms living together interact with each other and their non-living environment.
- Producers are the bottom of the food chain and are known as autotrophs.
- Ecosystems have living (biotic) parts and non-living (abiotic) parts.
- Producers use photosynthesis to make food (energy).
- Consumers include herbivores, carnivores, omnivores and detritivores; they cannot make their own food and are known as heterotrophs.
- Herbivores eat plants and are primary consumers.
- Carnivores eat other animals and are secondary or tertiary consumers.
- Omnivores eat both plants and animals; most humans are omnivores.
- Detritovores feed on the tissue of dead or decaying organisms.
- Complex interactions occur between species; for example, predator–prey or symbiotic relationships.
- Ecological niches of each species includes: habitat, nutrition and relationships with its own species and other species.

Measuring biodiversity

- Abiotic factors include water, humidity, temperature, light and pH.
- Biotic factors in an ecosystem are other living organisms.
- Each abiotic factor has a tolerance range and, within this, an optimum range for an organism.
- Species can be counted or measured using quadrats, transects, or capture, mark, release and recapture methods.
- Estimated average density = $\dfrac{\text{total number of individuals counted}}{\text{number of quadrats} \times \text{area of each quadrat}}$

Plants — the structure of producers

- Main organs of vascular plants: roots, stems and leaves.
- Root hairs greatly increase the surface area allowing more moisture and nutrients to be absorbed.
- Stems are transport tubes for plants.
  - Translocation is the movement of organic molecules up and down the plant.
  - Transpiration is the evaporation of water from the leaves.
- Leaf cells contain chloroplasts with chlorophyll, the green pigment that captures the light energy from the Sun to use in photosynthesis; this allows plants to be producers.
- Stomata are tiny pores in leaves where gases (water, carbon dioxide and oxygen) are exchanged with the atmosphere.
- Reproduction in flowering plants occurs when egg cells merge with a sperm (pollen grain) — fertilisation.
- Before fertilisation, a flower must be pollinated (when a pollen grain lands on the stigma); pollination can occur with help from: the wind, insects, other animals including birds.

Photosynthesis

- Producers (or autotrophs) produce their own food by capturing the energy of sunlight to make energy-rich glucose from carbon dioxide and water. This process is called photosynthesis.
- An overall chemical reaction for photosynthesis can be written as:

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

It can also be represented in chemical symbols as:

$$6CO_2 + 12H_2O \xrightarrow[\text{chlorophyll}]{\text{light energy}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

- Producers capture the energy of sunlight in chlorophyll, which is contained within membrane-bound organelles called chloroplasts.
- Chlorophyll is green because it reflects green light and best absorbs red and blue colours of the visible spectrum.
- Humans cannot make our own food since we lack chlorophyll; we are therefore consumers.

Cellular respiration

- The sum of all reactions occurring in an organism is its metabolism.
- Cellular respiration is the process by which glucose is broken down and the energy is made available for the cell in a usable form as ATP.
- When glucose is broken down in the presence of oxygen it is known as aerobic cellular respiration.
- An overall chemical reaction for aerobic cellular respiration can be written as:

$$\text{Glucose} + \text{oxygen} \xrightarrow{\text{enzymes}} \text{carbon dioxide} + \text{water} + \text{energy}$$

It can be represented in chemical symbols as:

$$C_6H_{12}O_6 + 6O_2 \xrightarrow{\text{enzymes}} 6CO_2 + 6H_2O + 36\text{–}38 \text{ ATP}$$

- The first stage of aerobic respiration takes place in the cytosol; it is called glycolysis.
- The second stage occurs in the mitochondria; this is where most of the energy is released for use by the cell.
- If oxygen is not available, the cells can respire for a short time without oxygen; this is called anaerobic respiration.
- Animals, including humans, produce lactic acid as the product of anaerobic cellular respiration.
- Plants produce ethanol and carbon dioxide and products when they undergo anaerobic cellular respiration.

Relationships in ecosystems

- Matter is recycled through ecosystems; ecosystems need an energy input.
- Energy enters the ecosystem as light energy, which is used in photosynthesis; this energy flows through the trophic (feeding) levels in the food web.
- There are producers that do not have access to light; these organisms use energy from chemical reactions as their source of energy, so they are referred to as chemosynthetic.
- The feeding relationships within an ecosystem are shown in food webs that contain many different food chains.
- Each feeding level in a food chain is called a trophic level; producers make up the first trophic level; herbivores (primary consumers) make up the second trophic level; carnivores make up the remaining trophic levels.
- Matter cycles through both the community and abiotic factors of ecosystems.
- The carbon cycle includes the processes of photosynthesis and cellular respiration.

- The nitrogen cycle includes nitrifying bacteria, which fix nitrogen from the air into nitrites, which can be absorbed by plants.
- Phosphate in rocks can be weathered and then moved by erosion so that plants can absorb and utilise this in proteins.
- An ecological pyramid is a useful tool in showing the trophic levels in an ecosystem.
- An energy pyramid shows how the flow of energy is reduced to just 10 per cent flowing to the next level.
- A pyramid of numbers shows the populations of organisms at each trophic level.
- A pyramid of biomass shows the dry mass of organisms at each level.

Changes in populations

- Population growth can be represented and determined mathematically with the following equation:

$$\text{Population growth} = (\text{births} + \text{immigration}) - (\text{deaths} + \text{emigration})$$

- Exponential growth can be seen when resources are unlimited and there is a lack of both predators and disease; an example of this is bacteria growth.
- The carrying capacity of a particular population within a community is the maximum number of individuals that can survive in that particular ecosystem with its finite resources.
- Agricultural practices have caused soils to become depleted of nutrients; artificial fertilisers containing nitrogen and phosphorus have been added. Water run-off has caused algal blooms (eutrophication).
- Insects populations have been affected by the use of both biological and chemical controls.
- Chemical methods using pesticides has resulted in bioaccumulation, i.e. as the pesticide moves up the trophic level it increases in concentration.
- Rabbits were first introduced in Victoria, but they have been so successful that they have devastated much good farming land by causing erosion.
- Cane toads have emigrated from Queensland across water habitats to the Northern Territory, killing the native animals that eat them.
- The Northern Pacific sea star has harmed both native marine species and the marine industry in Port Phillip Bay.

Adapting to dry conditions

- Australia is an island with very arid conditions and organisms in these arid and desert ecosystems have structural, behavioural and physiological adaptations to survive.
- The thorny devil has channels between its scales that are structural adaptations to collect the overnight dew.
- The spinifex hopping mouse is nocturnal (behavioural adaptation) and produces a very concentrated urine (physiological adaptation).
- Many desert animals, including the bilby, are nocturnal to increase their chance of survival in the harsh Australian desert.
- Plants also have structural adaptations to survive in the desert — these include small narrow leaves and silver or grey foliage, which may have a furry texture.
- Plants that are well adapted to dry conditions are called xerophytes (for example, cacti); some xerophytes are ephemeral, i.e. they have a short life cycle when water is available.
- Xerophytes that live for at least 3 years are called perennial and so they have structural adaptations to store water; cacti have thick leaves to store water.
- Drought tolerant plants can survive for a period of time without water; drought resistant plants can store water.
- Eucalypt leaves hang down vertically to reduce water loss in an arid environment.

Bushfires change ecosystems

- Many Australian plants have adaptations to survive bushfires.
- Small bushfires can be very useful for some plant populations in the community.
- Indigenous Australian peoples traditionally used fires as one of their many ways to manage the land.

- Some species of Australian plants need fire to germinate; for example, eucalypts have woody gumnuts that open after the heat of bushfires, which allows the seeds to fall out and germinate in the soil that has nutrients from the ash.
- The scale and intensity of the bushfire determines the impact on the ecosystem. The bushfires of 2020 were of such a large scale and so intense that some ecosystems may have been changed forever.

5.13.2 Key terms

abiotic factors the non-living features in an ecosystem
adenosine triphosphate (ATP) a form of energy released during cellular respiration that provides cells with the energy needed to perform their functions
aerobic respiration the breakdown of glucose to carbon dioxide using oxygen and releasing energy in the form of ATP
anaerobic respiration the breakdown of glucose to simpler substances, in the absence of oxygen, and release of energy as ATP
anther the part of a flower that produces pollen (the male gametes)
autotrophs *see* producer
bioaccumulation the magnification of concentrations of a substance such as a nonbiodegradable pesticide along the food chain; also known as biological magnification
biodiversity the variety of species of biological organisms, often in relation to a particular area
biotic factors the living things (organisms) in an ecosystem
birth rate the number of organisms within a population that are born within a particular period of time
capture, mark, release and recapture a sampling method used to determine the abundance of mobile animals
carnivores animals that eat other animals
carpel female reproductive organ of a flower, it consists of the stigma, style and ovary
carrying capacity the maximum population size that a particular environment can sustain
cellular respiration a series of chemical reactions in which the chemical energy in molecules such as glucose is transferred into ATP molecules, which is a form of energy that the cells can use
chemosynthetic organisms that produce organic material using energy released from chemical reactions rather than light
chlorophyll the green-coloured chemical in plants that absorbs the light energy so that it can be used in photosynthesis
chloroplast oval-shaped organelle in plants that are involved in the process of photosynthesis, which results in the conversion of light energy into chemical energy
commensalism the relationship between organisms where one benefits and the other is unaffected
community more than one population living in the same area at a particular time
competition the struggle among organisms for food, territory and other factors
consumer (heterotroph) an organism that relies on other organisms for its food
cross-pollination the transfer of pollen from stamens of one flower to the stigma of a flower of another plant of the same type
cytosol the fluid found inside cells
death rate the number of organisms within a population that die within a particular period of time
decomposer an organism that breaks down organic matter into inorganic materials
detritivores animals that feed on and break down dead plants or animal matter
drought resistant being able to store water and hence live for long periods of time without water
drought tolerant being able to tolerate a period of time without water
ecological niche the role or position of a species or population in its ecosystem in relation to each other
ecology the study of ecosystems
ecosystem communities of organisms that interact with each other and their environment
ectoparasite a parasite that lives on the outside of the body of its host organism
emigration the number of individuals leaving an area
endoparasite a parasite that lives inside the body of its host organism
energy pyramid a representation of the level of food energy at each level within a food chain
ephemeral describes lasting for only a very short time
eutrophication a form of water pollution involving an excess of nutrients such as nitrates and phosphorus, resulting in algal blooms and possible death of fish and other organisms

exponential growth a rapid increase in number or size, represented by a J-shaped graph
fertilisation fusion of the male sex cell and the female sex cell, in plants involves the fusion of pollen grain and egg cell
first-order consumer an organism that is within the second trophic level of a food chain (herbivores); also known as a primary consumer
flaccid limp, not firm
flower the structure in flowering plants (angiosperms) that contains reproductive organs
food chains a flow chart that shows the flow of energy from one organism to another as a result of feeding relationships
food webs diagram that shows interlocking food chains within an ecosystem
fumigants chemicals used in the form of smoke or fumes, to kill pests
fungicides chemicals used to kill fungal growth
gametes sex cells
glucose a six-carbon sugar (monosaccharide) that acts as a primary energy supply for many organisms
glycolysis the process (that does not require oxygen) in which glucose is broken down into simpler molecules and energy is released in the form of ATP
guard cells cells surrounding each stoma in a leaf enabling it to open or close depending on the availability of water
habitat where a species lives within the ecosystem
herbicides chemicals used to kill unwanted plants (weeds)
herbivores animals that eat only plants
immigration the number of individuals moving into an area
insecticides chemicals used to kill insects
insect pollination the transfer of pollen from one flower to another by insects
interspecific competition competition between organisms of the different species
intraspecific competition competition between organisms of the same species
introduced species an organism that has been released into an ecosystem in which it does not occur naturally
lactate *see* lactic acid
lactic acid an end product of anaerobic respiration in animals; also known as lactate
light energy sunlight energy or energy from an artificial light source
metabolism the chemical reactions occurring within an organism to maintain life
mitochondrion a small rod-shaped organelle that supplies energy to other parts of the cell
multicellular organism an organism that is made up of many cells
mutualism the relationship between two different organisms in which both benefit
nocturnal being active only at night
obligate anaerobes organisms that can respire only anaerobically (in the absence of oxygen)
omnivores animals that eat plants and other animals
optimum range the range, within a tolerance range for a particular abiotic factor, in which an organism (of a particular species) functions best
organelle a structure in a cell with a particular function
ovary in flowering plants, is the hollow, lower end of the carpel containing the ovules (the female egg cells)
parasite organisms that obtains resources from another organism (host) that it lives in or on, and can cause harm to
parasitism an interaction in which one species (the parasite) lives in or on another species (the host) from which it obtains food, shelter and other requirements
perennial means lasting for three or more years
phloem vascular tissue that transports organic substances (for example, sugars) within plants
photosynthesis a series of chemical reactions in the chloroplasts of plant cells that uses light energy, carbon dioxide and water to produce oxygen, water and sugars (food)
pistil the female reproductive organ of a flower that consists of one or more carpel (made up of the stigma, style and ovary)
plateau phase a state in which conditions are balanced and there is neither growth nor a decrease in number; also known as steady state or equilibrium
pollen grains the male gametes of a flower
pollination the transfer of pollen from the stamen (the male part) of a flower to the stigma (the female part) of a flower
pollinators animals that transfer pollen from one flower to another

population a group of individuals of the same species living in the same area at a particular time
population density the number of a species living within an area
population distribution the area inhabited by a plant or animal species
predator–prey relationship a relationship between organisms in which one species (the predator) kills and eats another species (the prey)
primary consumers the first consumers in a food chain; also known as a first-order consumers
producer (autotroph) the organism at the base of the food chain that does not need to feed on other organisms
pyramid of biomass a representation of the dry mass of organisms at each level within a food chain
pyramid of numbers a representation of the population, or numbers of organisms, at each level within a food chain
quadrats a sampling method used to estimate the distribution and abundance of organisms that are stationary or nearly stationary. The sampling area is typically 1 square metre.
root hairs hairlike extension of epidermal cells on plant roots
sampling methods techniques used to determine the density and distribution of various populations and communities within an ecosystem
second-order consumer an organism that is within the third trophic level of a food chain (carnivores); also known as a secondary consumer
self-pollination the transfer of pollen from the flower's own stamen to its stigma
sigmoid the shape of a graph that shows a population increasing in number then reaching a plateau
stamen male reproductive organ of a flower, it consists of the anther and the filament
steady state phase *see* plateau phase
stigma a female reproductive structure in a flower that receives the pollen
stomata pores that exchange gases found on the surface of leaves. They are bordered by guard cells that change the size of the opening of the stomata (singular = stoma).
style the tube-like female reproductive structure in a flower that connects the stigma to the ovary
symbiotic relationship a very close relationship between two organisms of different species. It may benefit or harm one of the partners.
thermoreceptors special cells located in your skin, part of your brain and body core that are sensitive to temperature
tolerance range the range of an abiotic factor in the environment in which an organism can survive
transects used to sample an area along a straight line, and is useful when environmental conditions vary along the sample line
translocation transport of materials, such as water and glucose, in plants
transpiration loss of water vapour mainly through stomata in the leaves (and sometimes from stems)
transpiration stream the movement of water through a plant as a result of loss of water from the leaves
trophic level a level within a food chain, food web or food pyramid
turgid firm, distended
vascular bundle group of xylem and phloem vessels within a plant
vectors are organisms that carry and disperse reproductive structures (for example, pollen) of a different species; organisms that carry a pathogen between other organisms without being affected by the disease caused by the pathogen
wind pollination the transfer of pollen from one flower to another by the wind
xerophytes plants adapted to dry conditions possessing structural and physiological adaptations for water conservation
xylem vessel vascular tissue that transports water and minerals from the roots up to the leaves
zero population growth the point at which the population does not increase in size

Resources

eWorkbooks	Study checklist (ewbk-3925) Literacy builder (ewbk-3926) Crossword (ewbk-3928) Word search (ewbk-3930)
Practical investigation eLogbook	Topic 5 Practical investigation eLogbook (elog-0440)
Digital document	Key terms glossary (doc-3450)

5.13 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. List the following to sequence the terms in the order of simplest to most complex.
   - Atoms
   - Cells
   - Molecules
   - Multicellular organisms
   - Organelles
   - Organs
   - Systems
   - Tissues
2. Match the term with its description.

Term	Description
a. Atom	**A.** The smallest unit that is life itself
b. Cell	**B.** Components from which cells are constructed
c. Molecule	**C.** Smallest unit of a substance that retains the properties of that substance
d. Organelle	**D.** Two or more atoms bonded together

3. Match the term with its description.

Term	Description
a. Biosphere	**A.** Individual composed of many specialised cells
b. Community	**B.** Group of organisms of the same species in the same area
c. Ecosystem	**C.** Dynamic system of organisms that interact with each other and the environment
d. Multicellular organism	**D.** Entire surface of the Earth and its organisms
e. Population	**E.** Populations of organisms living together in the same habitat

4. Match the type of relationship with its description.

Type of relationship	Description
a. Commensalism	**A.** Fungi in a termite's stomach enables them to digest the food that they eat and each cannot live without the other.
b. Interspecific competition	**B.** Tapeworm lives inside the intestine of a pig.
c. Intraspecific competition	**C.** Kangaroos and sheep compete for grass as a food source.
d. Mutualism	**D.** Lampreys attach themselves to sharks and feed on scraps of the shark's food without affecting the shark.

e. Parasite–host	**E.** Male kangaroos fight each other for the attention of females.
f. Predator–prey	**F.** Cats hunt and eat mice.

5. Identify the appropriate terms to complete the photosynthesis equation:

$$\underline{\hspace{3cm}} + \text{water} \xrightarrow[\underline{\hspace{2cm}}]{\text{light energy}} \underline{\hspace{3cm}} + \underline{\hspace{3cm}} + \text{water}$$

6. Identify the appropriate molecules to complete the photosynthesis equation.

$$6\underline{\hspace{2cm}} + 12\underline{\hspace{2cm}} \xrightarrow[\text{chlorophyll}]{\text{light energy}} \underline{\hspace{2cm}} + 6\underline{\hspace{2cm}} + 6H_2O$$

7. Identify the appropriate terms to complete the cellular respiration equation:

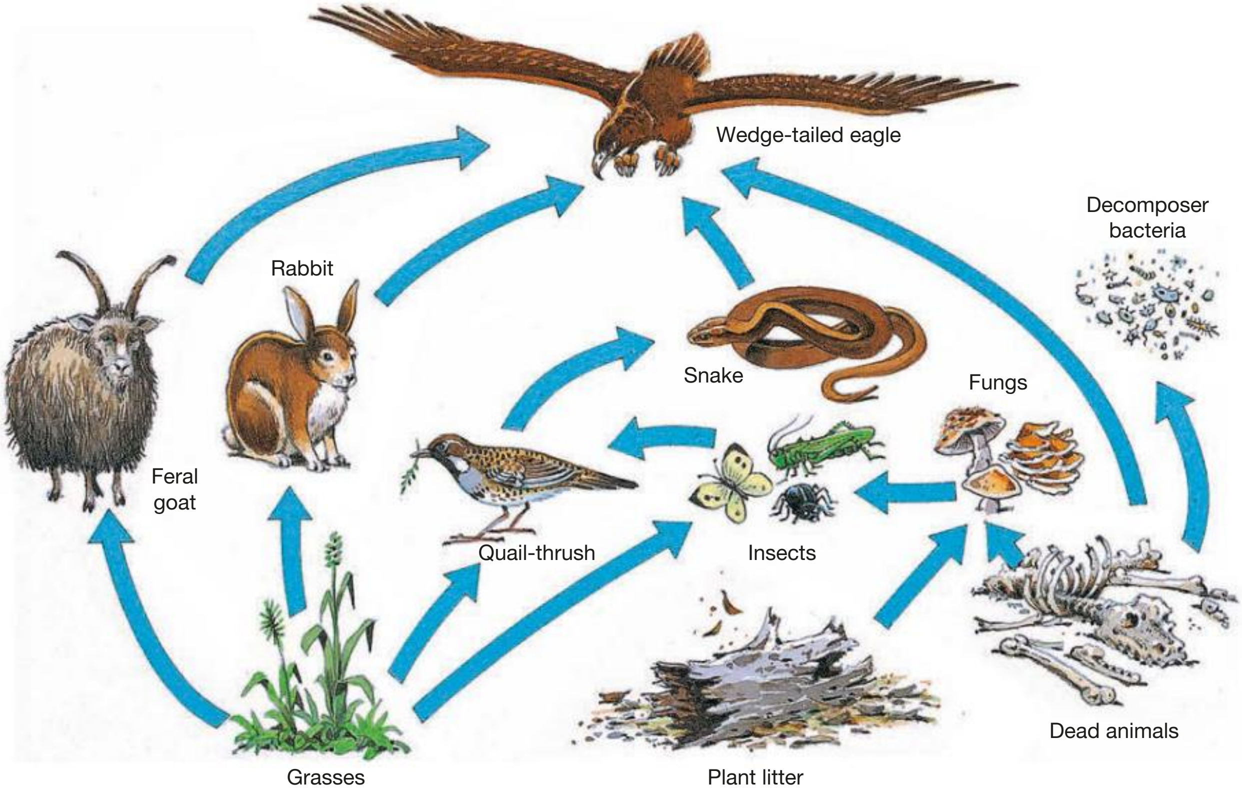
$$\text{oxygen} + \underline{\hspace{3cm}} \xrightarrow{\text{enzymes}} \underline{\hspace{3cm}} + \text{water} + \text{energy}$$

8. Identify the appropriate molecules to complete the cellular respiration equation:

$$O_2 + \underline{\hspace{3cm}} \xrightarrow{\text{enzymes}} \underline{\hspace{3cm}} + H_2O + \text{energy}$$

Apply and analyse

9. **MC** Use the information in the food web to select the best description of the feeding relationships of the wedge-tailed eagle within the food web.



A. First-order consumer and second-order consumer
B. Second-order consumer and third-order consumer
C. Second-order consumer, third-order consumer and fourth-order consumer
D. Third-order consumer and fourth-order consumer

10. For the following situations, identify the best sampling method.
a. To estimate the distribution and abundance of the fungi *Mycena interrupta*
b. To determine the distribution of *Xanthorrhoea* (Australian grass trees) along a sample that varies in its ecological conditions
c. To determine the abundance of the native rat *Rattus fuscipes*

11. MC Genevieve wanted to estimate the number of cockroaches in the backyard shed. On Sunday, she caught 20 cockroaches and placed a dab of orange paint on their backs, and then released them. Each night for the following week she captured cockroaches in the shed and made a note of how many had the orange paint mark on their back. Her results are shown in the table below.

Day	Total number of cockroaches captured	Number of tagged cockroaches
Monday	10	5
Tuesday	15	2
Wednesday	20	4
Thursday	18	6
Friday	22	3
Saturday	15	5

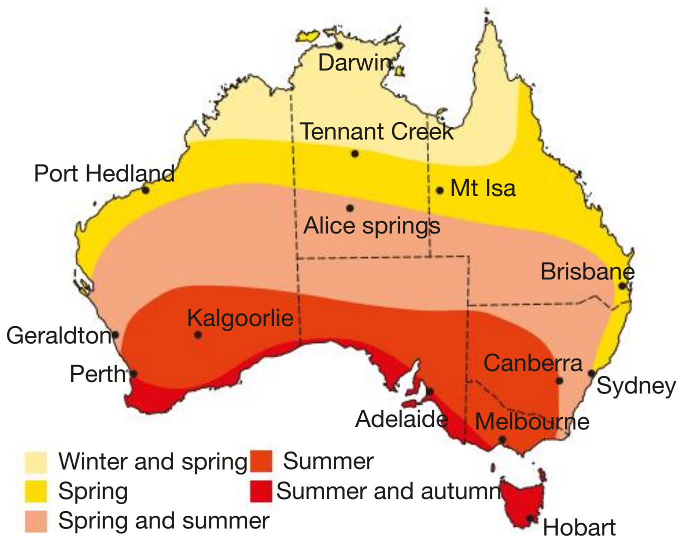
Based on her data from only her first capture, mark and release of cockroaches on Sunday, and her capture results on Monday to Saturday, estimate the total number of cockroaches using the capture–recapture method.

A. 40 cockroaches **B.** 60 cockroaches **C.** 80 cockroaches **D.** 100 cockroaches

Evaluate and create

12. SIS Consider the map of the bushfire season in Australia.

   a. When does the bushfire season occur in:
      i. Darwin
      ii. Melbourne
      iii. Hobart?
   b. Suggest a reason why the season occurs in broad horizontal bands across Australia.
   c. Why do you think bushfires occur in different seasons in different parts of Australia? Provide an example to explain your answer.



Fully worked solutions and sample responses are available in your digital formats.

on Resources

eWorkbook Reflection (ewbk-3038)

teachon

Test maker

Create customised assessments from our extensive range of questions, including teacher-quarantined questions. Access the assignments section in learnON to begin creating and assigning assessments to students.

RESOURCE SUMMARY

on Resources

Below is a full list of **rich resources** available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

5.1 Overview

eWorkbooks
- Topic 5 eWorkbook (ewbk-3915)
- Student learning matrix (ewbk-3914)
- Starter activity (ewbk-3917)
- Labelling the water cycle (ewbk-3896)

Interactivity
- Labelling the water cycle (int-8257)

Practical investigation eLogbook
- Topic 5 Practical investigation eLogbook (elog-0440)

Video eLessons
- Butterfly and tropical flower (eles-2647)
- Rain cycle (eles-2648)

5.2 Ecosystems

eWorkbook
- Food webs (ewbk-3898)

Video eLessons
- Dung beetle relocating his dung house (eles-2649)
- Decomposers (eles-2650)
- Jawed land leech (eles-2651)
- Tapeworm in human intestine (eles-2652)

5.3 Measuring biodiversity

eWorkbooks
- Estimating the size of a population (ewbk-3900)
- Abiotic factors in an ecosystem (ewbk-3902)

Practical investigation eLogbooks
- Investigation 5.1: Using quadrats (elog-0320)
- Investigation 5.2: Measuring abiotic factors (elog-0322)
- Investigation 5.3: The capture–recapture method (elog-0324)
- Investigation 5.4: Biotic and abiotic factors (elog-0326)

Interactivities
- Quadrat method (int-0984)
- The capture–recapture method (int-0985)

5.4 Plants — the structure of producers

eWorkbooks
- Labelling the structure of plant roots (ewbk-3904)
- Labelling parts of a flower (ewbk-3906)

Interactivities
- Structure of plant roots (int-3405)
- Labelling parts of a flower (int-8231)

5.5 Photosynthesis

Practical investigation eLogbooks
- Investigation 5.5: Looking at chloroplasts under a light microscope (elog-0328)
- Investigation 5.6: Detecting starch and glucose in leaves (elog-0330)
- Investigation 5.7: Out of the light (elog-0332)

5.6 Cellular respiration

Video eLesson
- Burning (eles-2655)

5.7 Relationships in ecosystems

eWorkbook
- Cycling of materials (ewbk-3908)

Interactivities
- A food chain (int-3462)
- Trophic levels (int-3464)

5.8 Changes in populations

eWorkbook
- Introduced pests (ewbk-3910)

Video eLessons
- Reducing your carbon footprint (eles-0163)
- Native rats fighting for their habitat (eles-1083)

Interactivity
- Pesticides (int-3458)

Weblink
- How wolves changed rivers

5.10 Bushfires change ecosystems

eWorkbook
- Amazing fire trees (ewbk-3912)

Practical investigation eLogbook
- Investigation 5.8: Germinating seeds with fire (elog-0334)

Weblinks
- Find your fire district
- Fire management

5.11 Thinking tools — SWOT analysis

Weblink
- BOM Annual climate statement

5.12 Project — Blast off!

ProjectsPLUS
- Blast off! (pro-0106)

5.13 Review

eWorkbooks
- Topic review Level 1 (ewbk-3919)
- Topic review Level 2 (ewbk-3921)
- Topic review Level 3 (ewbk-3923)
- Study checklist (ewbk-3925)
- Literacy builder (ewbk-3926)
- Crossword (ewbk-3928)
- Word search (ewbk-3930)
- Reflection (ewbk-3038)

Practical investigation eLogbook
- Topic 5 Practical investigation eLogbook (elog-0440)

Digital document
- Key terms glossary (doc-34850)

To access these online resources, log on to **www.jacplus.com.au**.

6 Inside the atom

LEARNING SEQUENCE

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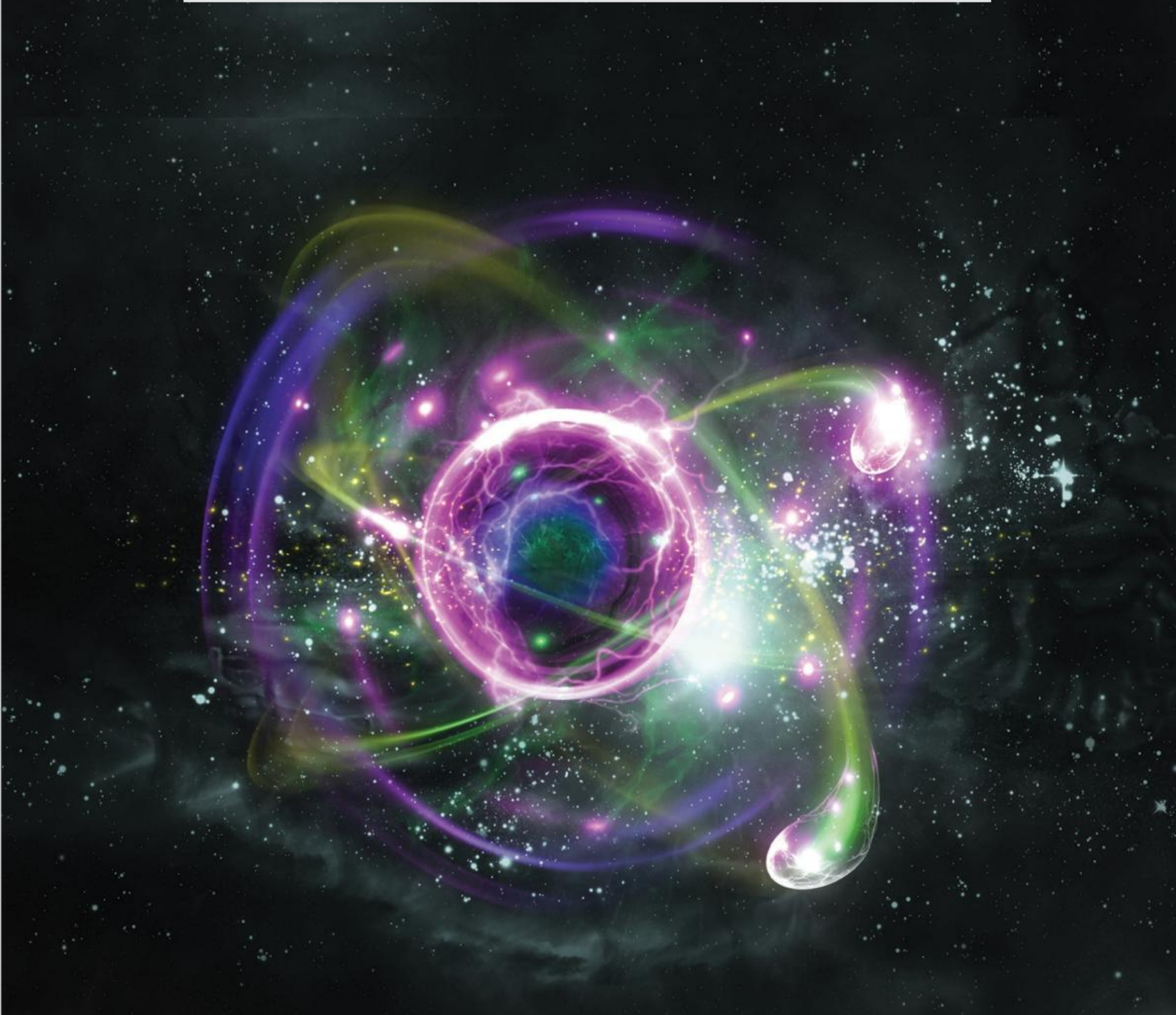
6.4 Using radioactivity 398
6.5 The dark side of radiation 406
6.6 Thinking tools — Concept maps and plus, minus, interesting charts 413
6.7 Review 416



6.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

6.1.1 Introduction

FIGURE 6.1 The atom was once thought to have a structure similar to this cake.

What does a cake have to do with chemistry? This model depicts an early idea for the structure of an atom. This was called the plum pudding model and was devised by English chemist J. J. Thomson. It showed negatively charged *electrons* embedded in a positively charged sphere. We now have a much better understanding of atoms. As atoms cannot be easily observed, this understanding has developed by using scientific models. These models are attempts to explain what we observe and understand how things work. Models are developed by scientists who perform experiments or make detailed observations and then fit all the data together into a model that makes sense. Models are very useful as they can be used to make predictions and to explain why something behaves the way it does. Most importantly, new discoveries can be used to improve models over time, so they are more useful and can better explain our observations.

Models are one example of how the scientific process keeps improving our understanding of the universe.

on Resources

Video eLesson The experiments that led to our understanding of the atom (eles-1780)

This video from the Story of Science demonstrates the fascinating experiments undertaken by scientists, which led to our evolving understanding of the atom.

6.1.2 Think about atoms

1. How did a plum pudding help scientists gain an understanding of atoms?
2. How did Lord Rutherford find out that the atoms in solid gold are mostly empty space?
3. What causes radioactivity?
4. Does 'radioactive' always mean 'dangerous'?
5. How is uranium used in a nuclear reactor?
6. What's the connection between radioactivity and fossils?
7. How is radioactivity used in the treatment of cancer?

6.1.3 Science inquiry

What is all matter made of?

You probably already know quite a lot about the different types of particles that make up substances. This knowledge is the first step in your quest to find out why substances behave the way they do.

Answer the questions below to find out how much you already know about the inside story on substances.

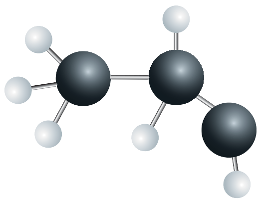
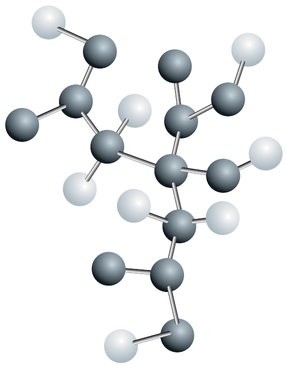
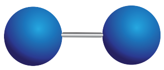
1. The substances around you and inside you can be placed into three groups — elements, compounds and mixtures.
   a. Which one of these groups contains substances that are made up of only one type of atom?
   b. Which one of these groups is the least likely to be found naturally in the Earth's crust?
   c. What is the difference between a compound and a mixture?
   d. Arrange the substances listed below into the three groups of substances to complete the affinity diagram below.

gold
blood
carbon dioxide
diamond
iron
sea water
air
copper
chocolate thick shake
table salt
soil
ammonia
concentrated hydrochloric acid
pure water
calcium
brass
sodium hydroxide
oxygen

SUBSTANCES

Elements	Compounds	Mixtures

2. Elements, compounds and mixtures are made up of tiny particles called atoms and molecules.
   a. How is a molecule different from an atom?
   b. Give an example of an element that is found as a molecule in its natural state.
   c. List two compounds that are made up of molecules.
   d. Name one compound that is not made up of molecules.
3. Name three different particles found inside an atom.
4. Which of the diagrams below represents:
   a. an atom of an element
   b. a molecule of an element
   c. a molecule of a compound?

i.

ii.

iii.

iv.


on Resources

eWorkbooks Topic 6 eWorkbook (ewbk-3130)
Student learning matrix (ewbk-3129)
Starter activity (ewbk-3132)

Practical investigation eLogbook Topic 6 Practical investigation eLogbook (elog-0154)

learnon Access and answer an online Pre-test and receive **immediate corrective feedback** and **fully worked solutions** for all questions.

6.2 Chemical building blocks

LEARNING INTENTION

At the end of this subtopic you will be able to describe how all matter is made of atoms, atoms are composed of tiny sub-atomic particles called protons, neutrons and electrons, and that protons and neutrons are located in the nucleus of an atom.

6.2.1 Models to explain the building blocks of matter

Most of our knowledge about the 'building blocks' of matter that we call atoms is less than 100 years old. But the idea that matter was made up of atoms was first suggested about 2500 years ago by the great philosopher and teacher Democritus. Since then, various theories and models of the atom have been accepted, rejected and modified. The timeline in figure 6.2 shows some of the important developments in our knowledge of the atom.

The current model of the atom accepted today consists of a tiny, dense **nucleus**, made up of the sub-atomic particles **protons** and **neutrons**, which is surrounded by **electrons** (see figure 6.3).

Atoms are tiny.

- Even the largest atoms are less than one billionth of a metre across. That's a millionth of a millimetre and about $\frac{1}{20\,000}$ of the diameter of the finest of human hairs.
- The nucleus is $\frac{1}{100\,000}$ of the diameter of an atom. If an atom were the size of the Melbourne Cricket Ground, the nucleus would be the diameter of a grain of rice.
- Atoms are mostly empty space. For example, a hydrogen atom is about 99.9999999999996 per cent empty space.

nucleus central part of an atom, made up of protons and neutrons; plural = nuclei

protons tiny particles found in the nucleus of an atom. Protons have a positive electrical charge and the same mass as a neutron

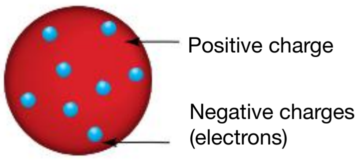
neutrons tiny particles found in the nucleus of an atom. Neutrons have no electrical charge and the same mass as a proton.

electrons extremely light (1800 times lighter than protons and neutrons) negatively charged particles inside an atom. Electrons orbit the nucleus of an atom.

FIGURE 6.2 Timeline of the development of the model of the atom

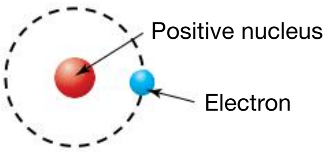
About 400 BC: Greek philosopher Democritus first suggested that all substances consisted of tiny indestructible particles called atoms.

1808: John Dalton's atomic theory proposed that:
- all matter consisted of tiny particles called atoms
- atoms could not be divided into smaller particles
- atoms of the same element were alike
- atoms combined in simple whole number ratios.

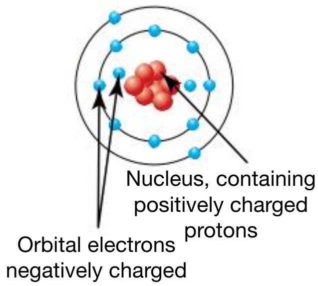


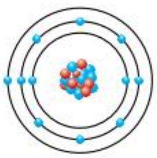
1897: English scientist Sir J. J. Thomson explained that the atom contained negatively charged particles called electrons. His model suggested that atoms were positively charged spheres with negatively charged electrons embedded in them like the fruit in a plum pudding.

1911: Lord Rutherford proposed that the atom consisted mostly of empty space with a dense nucleus containing positively charged protons in the centre. Negatively charged electrons orbited the nucleus. Although Lord Rutherford's model of the atom was essentially the same as today's accepted model, its one flaw was that it proposed that the orbiting electrons would eventually lose energy and spiral in towards the nucleus.



1913: Niels Bohr, a scientist who had studied with Rutherford, modified the model by suggesting that electrons orbit the nucleus at different energy levels. Only electrons with specific amounts of energy could exist at each level. His model proposed that electrons could move from one level to another by gaining or losing 'packets' of energy. Although Bohr's model explained why electrons did not spiral in towards the nucleus, it did not explain all of the known properties of atoms.

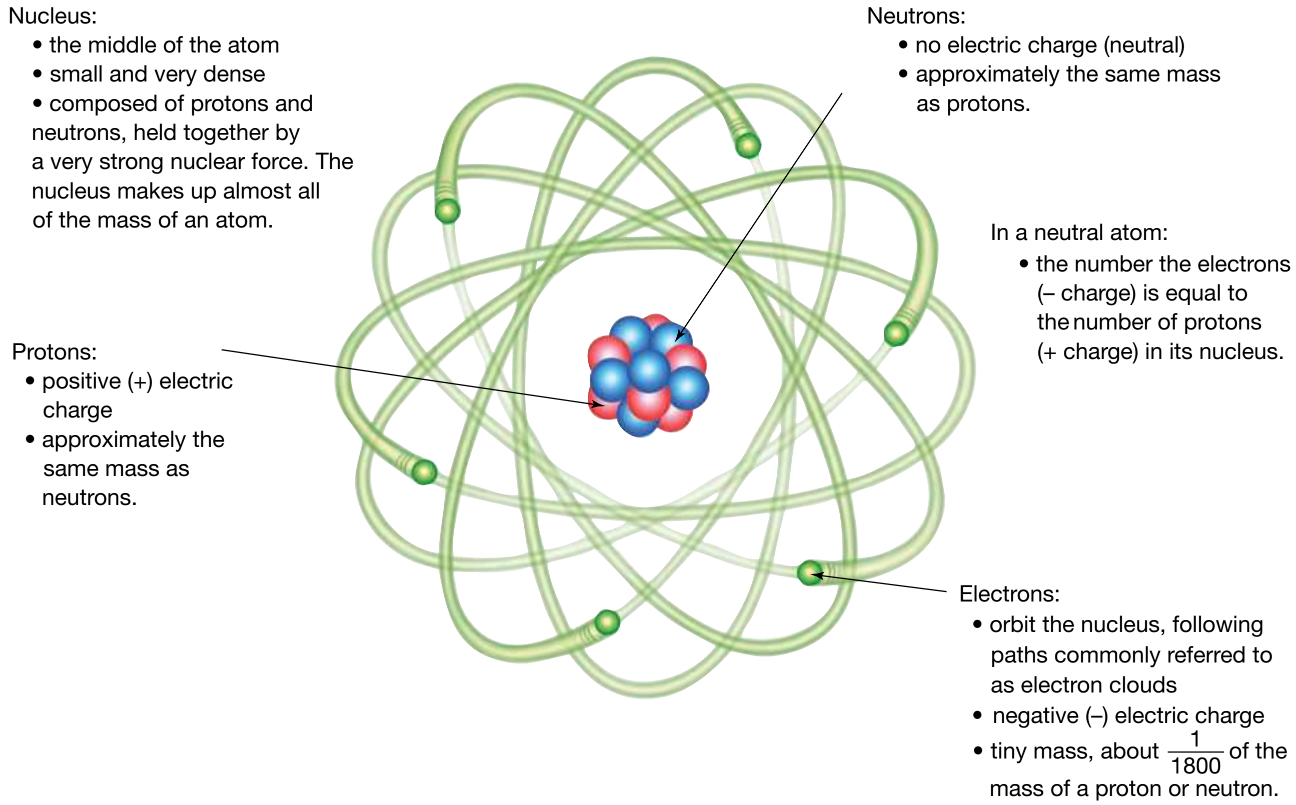




1932: Sir James Chadwick discovered that the nucleus contained particles called neutrons, as well as positively charged protons. Neutrons had no electric charge and a mass about the same as a proton.

eles-2657

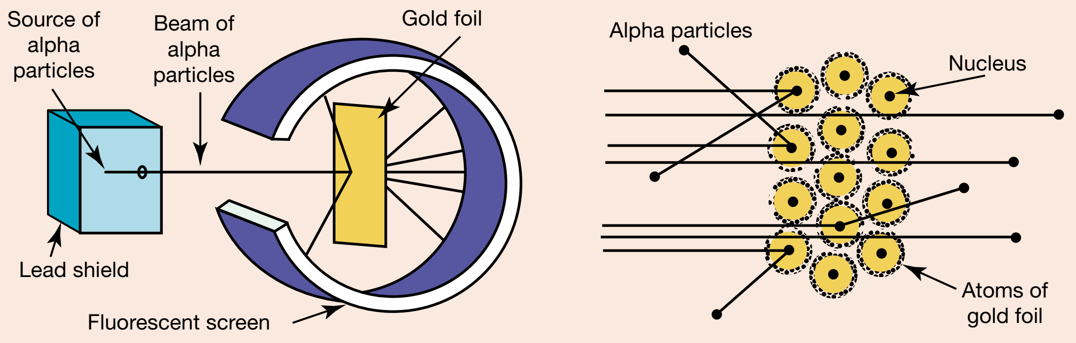
FIGURE 6.3 The current model of the atom



SCIENCE AS A HUMAN ENDEAVOUR: Lord Rutherford's model of the atom

Lord Rutherford's model of the atom was based on a series of experiments where:
- tiny positive alpha particles were fired at very thin sheets of gold foil
- the particles travelled was detected using a fluorescent screen.

FIGURE 6.4 An enlarged view of the gold foil experiment



Rutherford and his team observed that most of the particles went straight through the gold foil and very few were deflected back. This led them to several important conclusions:

- Rutherford explained that the few particles that were deflected back were repelled by a very small, positively charged nucleus in the atoms of the gold.
- Most of the alpha particles continued through the foil because each gold atom consists mainly of empty space.
- Lord Rutherford said later that his observations were about as credible as if you had fired a 16-inch shell at a piece of tissue paper and it had come back and hit you!

elog-0150

INVESTIGATION 6.1

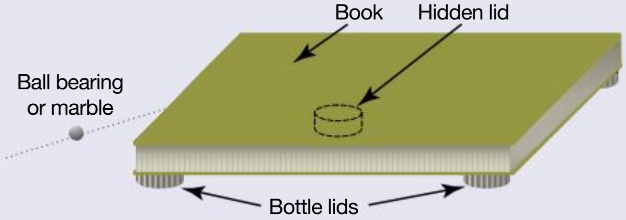
Exploring models of the atom

Aim

To explore Rutherford's experiment

Materials

- a hardcover book of at least A4 size
- 5 plastic soft drink bottle lids
- a 10 mm diameter ball bearing or 12 mm diameter marble



Method

1. Support the book on a benchtop using a bottle lid under each corner.
2. Have one member of your group lift the book, place the fifth bottle lid somewhere in the area surrounded by the other four lids and replace the book. The fifth lid represents the nucleus of the atom in this model.
3. After the other members of your group turn around, they take turns to roll the ball bearing or marble under the book to find the location of the 'nucleus'.

Results

Record the number of times the ball bearing or marble is rolled before striking the 'nucleus' for the first time.

Discussion

1. Comment on how difficult it is to locate the 'nucleus' in this model.
2. What is represented in this model of Rutherford's experiment by:
   a. the area under the book that is surrounded by the four lids
   b. the ball bearing or marble?
3. a. Recall that the plum pudding model does not contain a nucleus. Write a hypothesis for this experiment according to the plum pudding model.
   b. Based on your observations justify why this cannot be the plum pudding model of the atom.

Conclusion

Write a conclusion to this investigation as a response to the aim.

SCIENCE INQUIRY SKILLS: Repeatability

Scientists perform the same experiment multiple times and then analyse all the results. This repetition provides the most accurate results and allows scientists to draw conclusions with confidence.

DISCUSSION

Models of the atom have changed greatly over the past century. Do we now understand the atom completely, or could our models improve further? Learning from the past, how might such improvements be made?

on Resources

eWorkbook — Chemical building blocks (ewbk-3134)
How big is an atom? (ewbk-3136)

assess**on** — Additional automatically marked question sets

6.2 Exercise

learn**on**

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. MC Where is most of the atom's mass located?
   A. Protons
   B. Neutrons
   C. Electrons
   D. Nucleus
2. According to the plum pudding model, the atom is a ______________ with ______________ embedded in it like the fruit in a plum pudding.
3. What is the main difference between John Dalton's model of the atom and the models of Thomson, Rutherford and Bohr?
4. Complete the following table by including one example for each pair.

TABLE Comparison of sub-atomic particles

	Protons and electrons	Protons and neutrons	Electrons and neutrons
Similarity			
Difference			

Apply and analyse

5. Why did most of Rutherford's alpha particles go through the thin sheets of gold foil?
6. What was the main weakness of the Rutherford model of the atom?
7. SIS Why was it important for Rutherford to fire many alpha particles at the gold atoms?

8. SIS Explain why it is not surprising that the neutron was discovered quite a long time after the electron and proton.
9. Draw a diagram of the modern model of the atom and include the following labels.
proton, neutron, electron, positive, negative, neutral, nucleus

Evaluate and create

10. SIS Is the current model of the atom proven? Explain your answer.

Fully worked solutions and sample responses are available in your digital formats.

6.3 Stability and change — inside the nucleus

LEARNING INTENTION

At the end of this subtopic you will be able to explain how natural radioactivity arises from the decay of nuclei in atoms.

6.3.1 Neutrons and isotopes

At the centre of every atom is a tiny, solid core called the nucleus. Within the nucleus, protons and neutrons are usually held together by incredibly strong forces. Some of the mysteries of radioactivity can be unravelled by taking a closer look inside the nucleus.

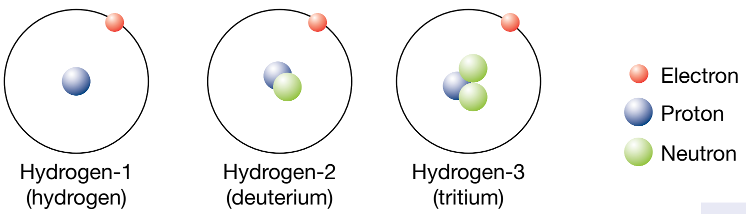
All atoms of a particular element have the same number of protons. However, often the number of neutrons in atoms of the same element is different. Such atoms have the same atomic number but different mass numbers.

Atoms of the same element with different mass numbers are called **isotopes**.
- Most elements exist as two or more isotopes.
- These isotopes all have the same chemical properties, but different masses.

For example, hydrogen has three isotopes. Each of the three isotopes has one proton. However, the different isotopes have 0, 1 or 2 neutrons respectively.

eles-2658

FIGURE 6.5 The three isotopes of hydrogen. Hydrogen-2 and hydrogen-3 are also known as deuterium and tritium respectively.



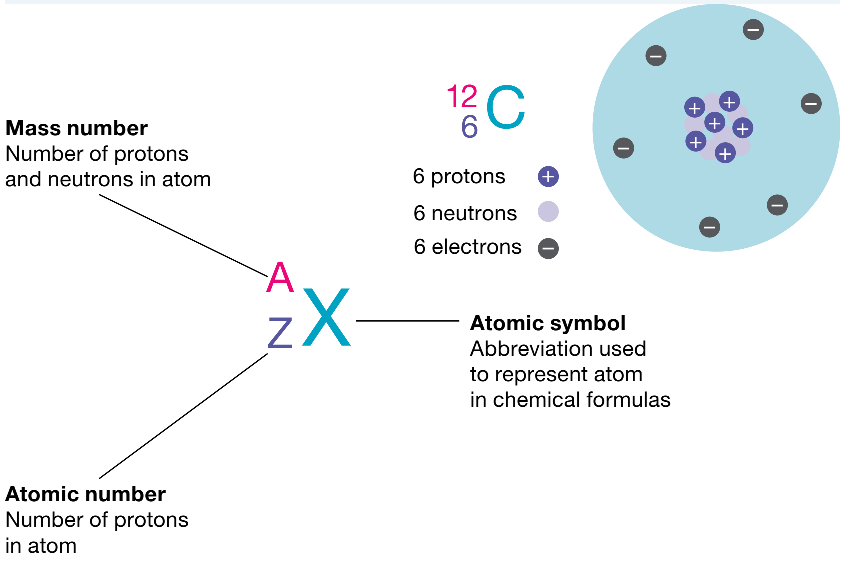
isotopes atoms of the same element that differ in the number of neutrons in the nucleus

Naming isotopes

Nuclide notation (figure 6.6) is used for atoms and can represent different isotopes. For example, the three isotopes of hydrogen can be represented as ${}^{1}_{1}H$, ${}^{2}_{1}H$, ${}^{3}_{1}H$.

Isotopes are also named with the element name and mass number; for example, hydrogen-3, as shown in figure 6.5.

FIGURE 6.6 Nuclide symbol notation



EXTENSION: Why are they called isotopes?

The word *isotope* is derived from the Greek words *isos*, meaning 'equal', and *topos*, meaning 'place'. It came about because even though each isotope of the same element had different numbers of neutrons and therefore different weights, they occupied the same place on the periodic table of the elements.

Stable or unstable atoms

- In **stable** atoms, the protons and neutrons found in the nucleus are held together very strongly.
- In **unstable** atoms, the neutrons and protons in the nucleus are not held together as strongly.
- Unstable isotopes **decay** to form other elements. These isotopes are said to be radioactive and are called radioactive isotopes, or **radioisotopes**.

For example, consider two isotopes of carbon, carbon-12 and carbon-14, which have identical chemical properties. However, the nucleus of carbon-14 is not stable and disintegrates naturally. Carbon-12 is a stable isotope while carbon-14 is a radioactive isotope.

nuclide a type of atom characterised by the number of protons and the number of neutrons in its nucleus

stable a nucleus that does not change spontaneously. The protons and neutrons in the nucleus are held together strongly.

unstable an atom in which the neutrons and protons in the nucleus are not held together strongly

decay to transform into a more stable particle

radioisotope a radioactive form of an isotope

TABLE 6.1 Examples of stable and unstable (radioactive) isotopes of carbon and uranium

Element	Symbol	Number of protons	Number of neutrons	Stable or radioactive?
Carbon-12	${}^{12}_{6}C$	6	6	Stable
Carbon-14	${}^{14}_{6}C$	6	8	Radioactive
Uranium-235	${}^{235}_{92}U$	92	143	Radioactive
Uranium-238	${}^{238}_{92}U$	92	146	Stable

6.3.2 Radioactivity

Natural and artificial radioactivity

Natural radioactivity is radioactivity emitted from matter without energy being supplied to atoms. There are about 50 isotopes that emit radioactivity naturally. They exist in the air, in water, in living things and in the ground. Most radioactive isotopes (about 2000 in total) are made radioactive artificially by bombarding their atoms with sub-atomic particles like protons and neutrons.

Nuclear radiation

The energy emitted by radioactive substances is called **nuclear radiation** because it comes from the nucleus. Lord Rutherford showed that there were three different types of nuclear radiation: **alpha particles**, **beta particles** and **gamma rays**.

nuclear radiation radiation from the nucleus of an atom, consisting of alpha or beta particles, or gamma rays

alpha particles positively charged nuclei of helium atoms, consisting of two protons and two neutrons

beta particles charged particles (positive or negative) with the same size and mass as electrons

gamma rays high-energy electromagnetic radiation produced from some radioactive decay; the radiation has no mass and travels at the speed of light

TABLE 6.2 The three types of nuclear radiation

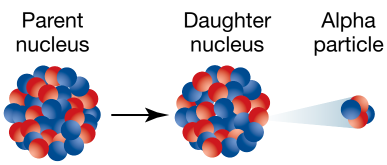
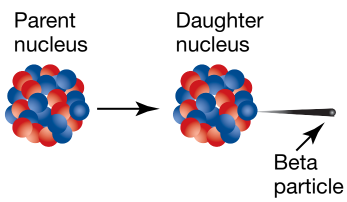
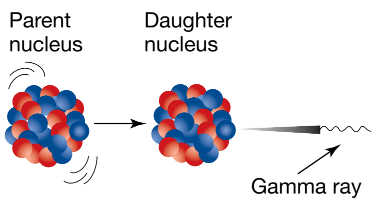
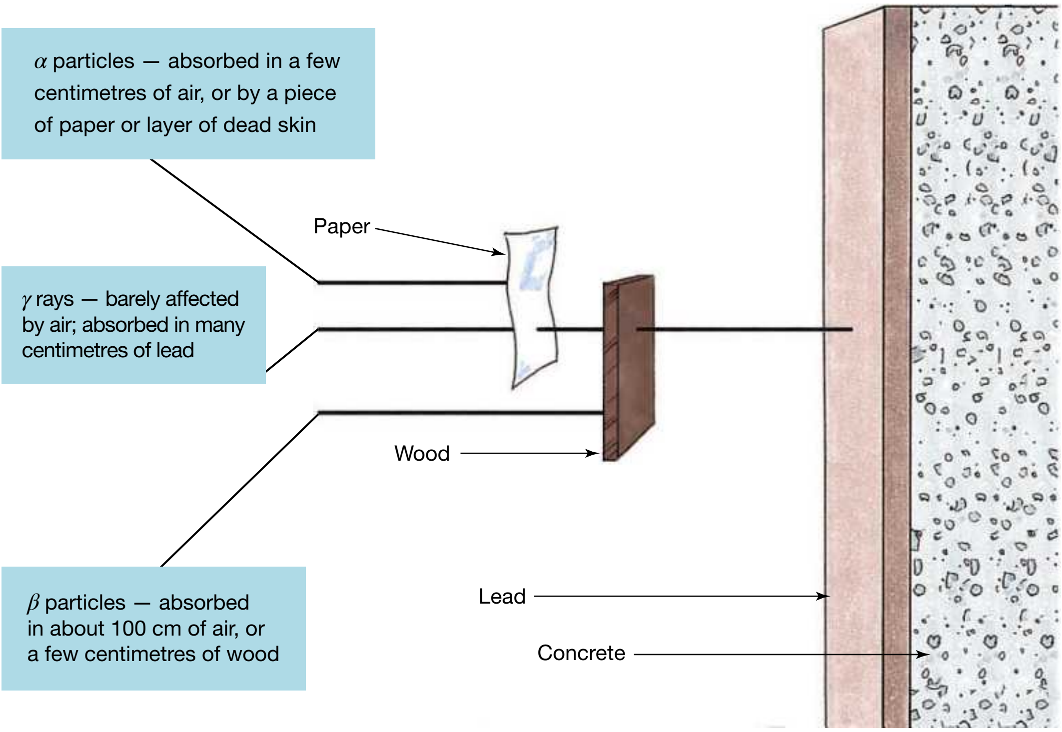
Nuclear radiation	Alpha particles	Beta particles	Gamma rays
Symbol	α	β	γ
Description	Helium nuclei that contain two protons and two neutrons, so they are positively charged	The same size and mass as electrons, can have a negative or positive electric charge and can travel at speeds as high as 99 per cent of the speed of light	Not particles, but bursts of energy released after alpha or beta particles are emitted; travels at the speed of light
Diagram of decay			
Penetration and danger to health	Cannot travel easily through materials and can be stopped by a sheet of paper or human skin. They pose little hazard to the external body but can cause serious damage if breathed in, eaten or injected.	Can penetrate human skin and damage living tissue, but they cannot penetrate thin layers of plastic, wood or aluminium	Highly penetrating. They can cause serious and permanent damage to living tissue and can be stopped only by a thick shield of lead or concrete.

FIGURE 6.7 The different penetrating powers of alpha (α), beta (β) and gamma (γ) radiation



on Resources

Video eLesson Smashing atoms in CERN (eles-1085)

6.3.3 The lives and half-lives of radioisotopes

The nuclei of different radioactive substances decay at different rates.

- The **half-life** of a radioisotope is the time taken for half of all the nuclei in a sample of a radioisotope to disintegrate or decay.
- Half-lives can vary from microseconds to billions of years.

half-life time taken for half the radioactive atoms in a sample to decay — that is, change into atoms of a different element

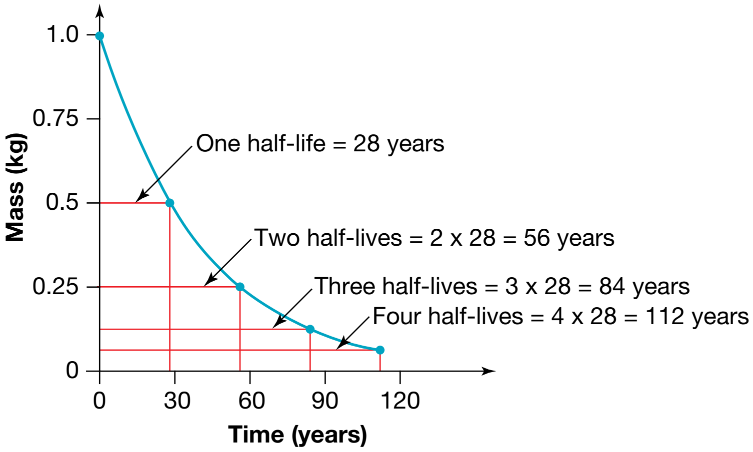
TABLE 6.3 The half-life of an isotope and the fraction remaining after each half-life

Number of half-lives	Fraction remaining
1	$\frac{1}{2}$
2	$\frac{1}{4}$
3	$\frac{1}{8}$
4	$\frac{1}{16}$

Uranium is probably the best known of the radioisotopes. There are three naturally occurring isotopes of uranium: uranium-238, uranium-235 and uranium-234.

- Each of the isotopes spontaneously disintegrates or decays, producing alpha particles and gamma rays.
- Each isotope has its own half-life; that is, the time taken for the concentration to fall to half its initial value.
- The half-lives of each of the uranium isotopes are more than a billion years.

FIGURE 6.8 A graph showing the radioactive decay of strontium-90, which has a half-life of 28 years



6.3.4 Background radiation

We are all exposed to background radioactivity every day. Fortunately, it is quite safe.

- Most of it comes from naturally occurring radioactive elements in the Earth's atmosphere and crust.
- Most of the background radiation is from radon, which is produced during the breakdown of other radioisotopes; for example, uranium and thorium.
- A smaller amount comes from outer space in the form of **cosmic radiation**, mostly in the form of high energy protons emitted by stars, including the Sun. The word cosmic comes from the Greek word *kosmos*, meaning 'universe'. The Earth's atmosphere protects us from the dangers of cosmic radiation, as we will discover in topic 9.

There are even small amounts of radioisotopes in the human body, including hydrogen-3 (tritium), carbon-14 and potassium-40.

cosmic radiation naturally occurring background radiation from outer space

DISCUSSION

Most naturally occurring radioisotopes on Earth were created before the planet was formed. Given the Earth is approximately 4 billion years old, what does that tell us about the half-life of these radioisotopes?

Carbon-14 has a half-life of only 5700 years yet is 1.1% of all naturally occurring carbon. How can this observation be explained?

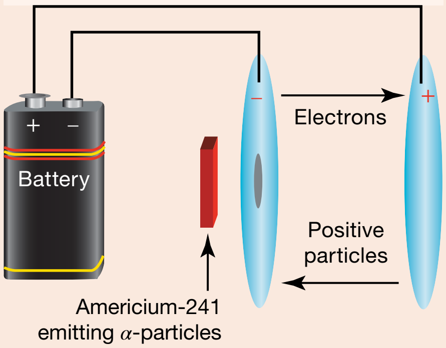
6.3.5 Smoke alarms

SCIENCE AS A HUMAN ENDEAVOUR: Using radiation to detect smoke

Smoke alarms are an example of radioisotopes used routinely in the home. They contain a tiny amount of americium-241, an alpha particle emitting radioisotope. Smoke alarms work by setting up a small electrical circuit in the detector. When that circuit is disrupted by smoke, the alarm sounds.

1. Alpha particles from americium-241 knock electrons off molecules in the air, creating positive particles and free electrons.
2. These charged particles are attracted to two oppositely charged plates, setting up a small current.
3. When the current flows there is no alarm.
4. However, when smoke particles enter the detector, they attach to the positive particles making them neutral.
5. This disrupts the current and the siren sounds.

FIGURE 6.9 What happens in the ionisation chamber?



Resources

Interactivity Radioactive half-life (int-1652)

eWorkbook Top ten elements (ewbk-3138)

assess on Additional automatically marked question sets

6.3 Exercise

learnon

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Select your pathway

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

Remember and understand

1. State what each letter represents in a nuclide symbol, ${}^{A}_{Z}X$.
   a. A **b.** Z **c.** X
2. Match the terms with the definitions in the following table.

Terms	Definition
a. Atomic number	**A.** Mass number – number of protons
b. Number of neutrons	**B.** Number of protons + number of neutrons
c. Mass number	**C.** Number of protons

3. Complete the following table.

TABLE Nuclide notation of different elements

Nuclide symbol	Atomic number	Mass number	Protons	Neutrons
${}^{14}_{6}C$				
	19	39		
			15	17
		31		16
	92			146

4. Identify one similarity and one difference between two particles that are isotopes.
5. Alpha particles are the heaviest type of radiation. Fill in the following table with the properties of alpha particles.

TABLE Properties of alpha particles

Charge	Protons	Mass number	Nuclide symbol

6. How are we protected from cosmic radiation from outer space?

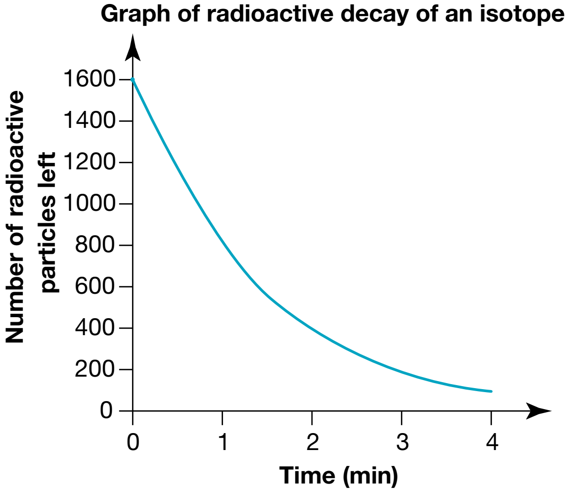
Apply and analyse

7. Are the atoms ${}^{230}_{93}X$ and ${}^{239}_{94}X$ isotopes of the same element? Explain.
8. The half-life of an isotope of tritium is 4500 days. How many days will it take an amount of tritium to fall to a quarter of its initial mass?
9. An atom of uranium-238, ${}^{238}_{92}U$, decays by emitting a single alpha particle. Write the nuclide symbol for the resulting atom. Explain how you got your answer.

10. Explain why the isotopes of some elements are radioactive.
11. State the type of nuclear radiation described by the following statements.
    a. A radioactive particle that has the same size and mass as an electron
    b. A radioactive particle that is made up of two protons and two neutrons
    c. The type of radiation that can penetrate the human body and can be stopped only by a thick shield of lead or concrete
    d. A radioactive particle that can travel almost at the speed of light.

Evaluate and create

12. **SIS** The graph shows the decay of a radioisotope over 4 minutes.
    a. What is the half-life of this isotope?
    b. How many radioactive particles would be left after 5 minutes?
    c. When the decay takes place in a sealed container, helium gas is collected. Name one type of radiation produced in the decay.



13. **SIS** A scientist wished to determine the type of radiation emitted by a radioisotope. She had three materials (paper, plastic and lead) and an instrument called a Geiger counter, which detects nuclear radiation. She covered the radioisotope with each of the three materials and measured the radiation that passed through each material. The results of her experiment are shown in the table provided.

TABLE Results of radioactivity experiment

Material	Effect on Geiger counter readings
Paper	No effect on readings
Plastic	Readings fell by two-thirds
Lead	Large fall in readings

    a. Identify the independent variable in this experiment.
    b. Identify the dependent variable in this experiment.
    c. Identify a controlled variable in this experiment.
    d. Complete the following table to determine whether certain variables should be controlled in this experiment.

TABLE Experiment variables

Variable	How could this variable affect the DV?	Should this variable be controlled? (Y/N)
The thickness of the material covering the radioisotope		
How far the Geiger counter is placed from the radioisotope		
The scientist wore her lab coat for only some measurements		

    e. What type of nuclear radiation does this radioisotope emit? Explain your answer, with reference to the data.

Fully worked solutions and sample responses are available in your digital formats.

6.4 Using radioactivity

LEARNING INTENTION

At the end of this subtopic you will be able to explain that natural radioactivity arises from the decay of nuclei in atoms and how we use radioisotopes in a variety of fields.

6.4.1 Radioisotopes

on Resources

Video eLesson The mystery of radium (eles-1779)

SCIENCE AS A HUMAN ENDEAVOUR: Using radioisotopes

In 1903, Marie Curie, her husband Pierre and Henri Becquerel were awarded the Nobel Prize in Physics for their discovery of radioactivity and their work on uranium. Little did they know that their discoveries and investigations would change the course of history.

They could not have imagined that their work would lead to the development of nuclear weapons capable of killing millions of people, nuclear power plants that generate electricity, and radioactive isotopes that can be used to treat cancers and detect life-threatening illnesses.

Radioisotopes are used in industry, research, and medicine. They can be used as radioactive 'tracers' to follow the movement of substances through liquids (for example, sediment movement in rivers and the movement of substances in the blood). Radioactive isotopes are also used in smoke detectors, soil analysis, pollution testing, measuring the thickness of objects, in criminology, and as we will explore next, in dating samples from archaeological sites and geological formations.

Radiometric dating

Naturally - occurring radioisotopes can be used to calculate the age of samples from archaeological sites and in determining the age of geological formations. This technique is called **radiometric dating**.

One of the most useful types of radiometric dating is **radiocarbon dating**, which uses the isotope carbon-14 with a half-life of 5700 years. Carbon is a very common element in living organisms, so the amount of carbon-14 left in a fossil or in an archaeological sample can be used to determine how long ago that organism died.

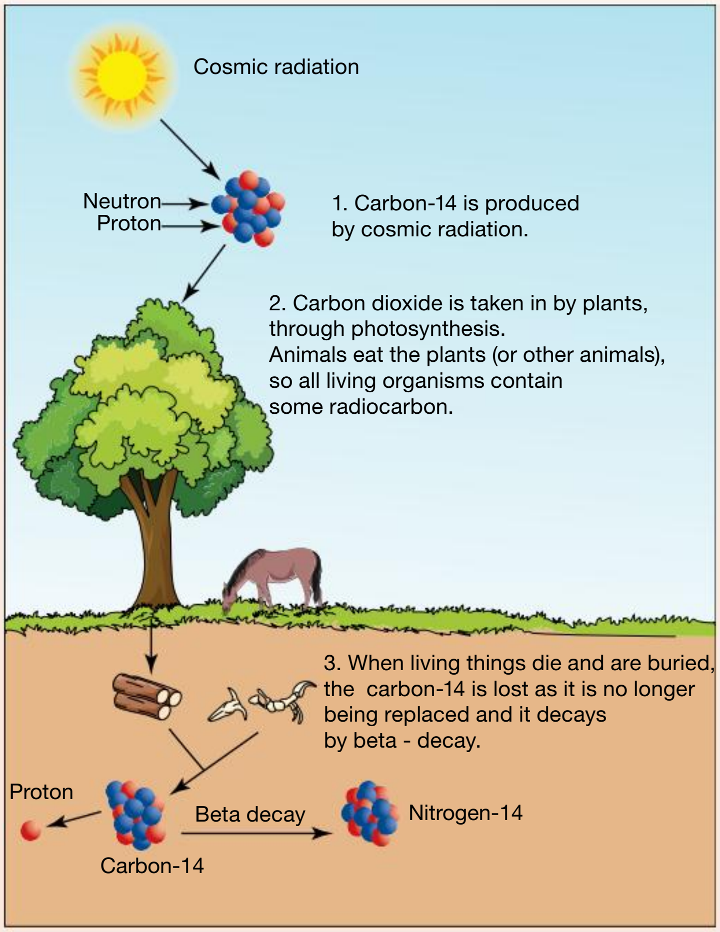
The process, shown in figure 6.10, is as follows:

1. Carbon-14 is produced by cosmic radiation, so that a small amount of all carbon is radiocarbon.
2. Carbon dioxide is constantly being taken in by plants, which are eaten by animals, so all living organisms contain some radiocarbon.
3. When living things die, the decaying radiocarbon is no longer being replaced.
4. Since all fossils were once living, their age can be determined by measuring the amount of radiocarbon remaining.

radiometric dating determining the ages of rocks and fossils based on the rate of decay or half-life of particular isotopes

radiocarbon dating a method of determining the age of a fossil using the remaining amount of unchanged radioactive carbon

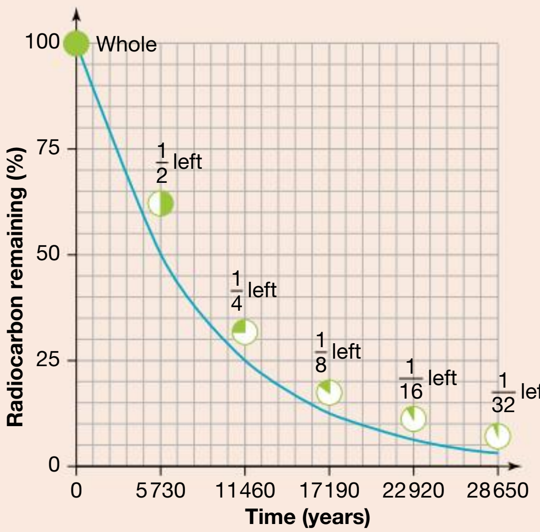
FIGURE 6.10 Carbon-14 generation and decay and its application in radiocarbon dating



After 5700 years, only half of the usual amount of radiocarbon will be left. A graph can be used to estimate the age of a sample. After about 50 000 years, the amount of radiocarbon becomes too small to measure accurately.

All rocks contain small amounts of radioactive elements such as uranium and potassium. The age of older rocks, and the fossils within them, can be determined by using radioactive elements with longer half-lives. For example, uranium–lead dating can be used to date rocks from 1 million to over 4.5 billion years old, using the decay of uranium-238 to lead-206 and uranium-235 to lead-207. This dating method has a precision of 0.1–1 per cent.

FIGURE 6.11 The decay of a sample of pure radiocarbon



EXTENSION: Consequences of working with radioactivity

Radioactivity was discovered by accident. French physicist Henri Becquerel discovered radioactivity while investigating the fluorescence of uranium salts in 1896. When he developed a photographic plate that had been left in a drawer near his benchtop, he found that it had been fogged up by radiation from the uranium salts.

This effect of radioactivity is now used in a protective device worn by people who work with radioactive materials. The 'fogging' of the film in this device measures the amount of radioactivity they have been exposed to.

Becquerel was the first scientist to report the effects of radioactivity on living tissue.

Our modern understanding of radiation has only been developed in the past century. Based on what you have learned so far, what do you expect were the consequences of working with radioisotopes for the early adopters in the below examples:

- scientists such as Henri Becquerel who worked closely with uranium salts
- watchmakers who painted the hands and numbers on watch faces with a luminescent, radioisotope radium-226 (workers used to form 'points' on their brushes by licking the bristles)?

FIGURE 6.12 This watch has been hand painted in luminescent radium paint.

6.4.2 Radioisotopes and nuclear power

The radioactive properties of uranium are used in the generation of electricity in **nuclear reactors**. Australia is one of several countries that have large high-grade deposits of uranium, which can be used in reactors.

The steps below describe the production of energy in a nuclear reactor.

1. Uranium is converted to uranium dioxide and then sealed in rods, called **fuel rods**.
2. The uranium undergoes a **fission** reaction in the reactor when neutrons are fired at the radioactive uranium (figure 6.13).
3. This causes the uranium nuclei to split and form two new elements, releasing neutrons, radiation and *heat* in the process.
4. This heat energy is used to heat water to produce steam, which is used to turn the turbines that generate the electricity (figure 6.14).

The process of steam driven turbines to produce electricity is described in detail in topic 10.

WHAT DOES IT MEAN?

The word *fission* comes from the Latin word *fissio*, meaning 'to split'.

nuclear reactors power plants where the radioactive properties of uranium are used to generate electricity
fuel rods one of the rods that form the fuel source of a nuclear reactor; contains the fissile nuclides needed to produce a nuclear chain reaction
fission splitting of the nuclei of large atoms into two smaller atoms and several neutrons, releasing radiation and heat energy

eles-2659

FIGURE 6.13 An example of a nuclear fission reaction

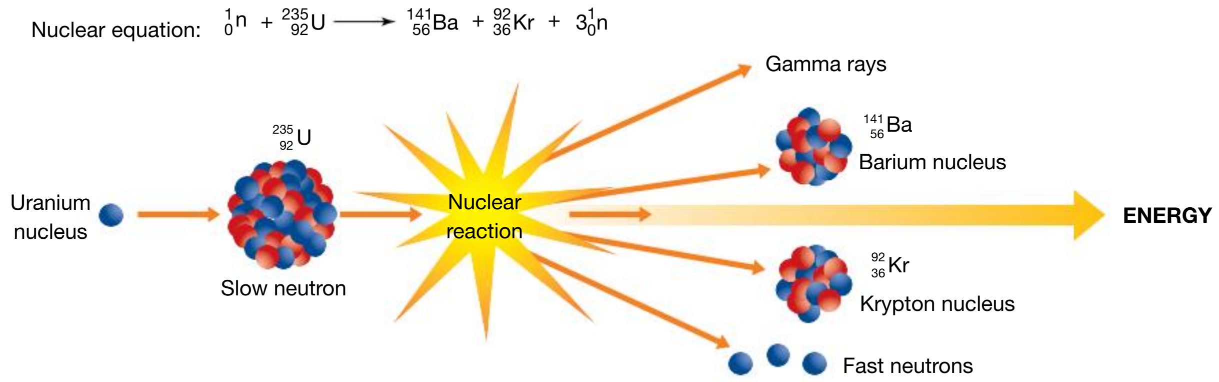
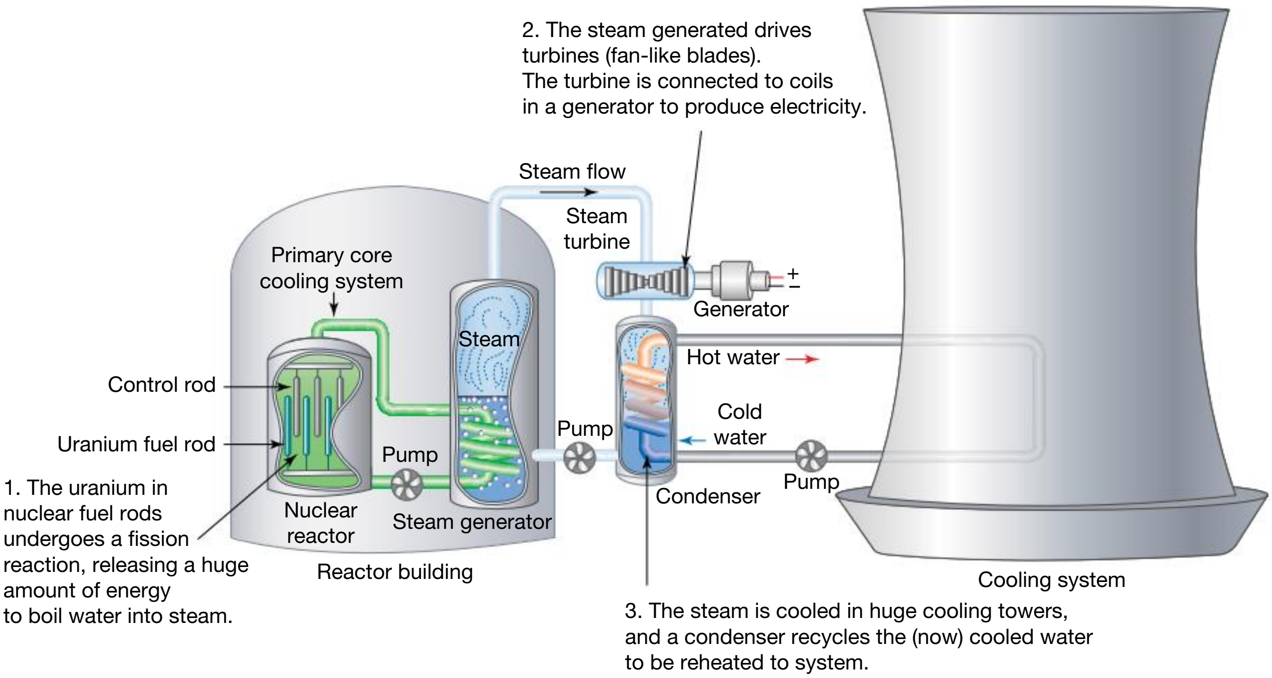


FIGURE 6.14 The heat from nuclear fission reactions creates steam from water, which drives a turbine to generate power.



DISCUSSION

This process of nuclear power generation is very similar to coal- and gas-fired power plants, although different sources of heat to boil water are used. What are some of the advantages of nuclear reactors over power stations that use fossil fuels? Are you aware of any disadvantages associated with nuclear reactors? Taking both the advantages and disadvantages into consideration, should we replace ageing coal-fired power stations with nuclear reactors?

Fast breeders

In some countries, fast breeder reactors use the artificial radioisotope plutonium-239 as a fuel. Plutonium-239 is made by bombarding uranium-238 with fast-moving neutrons (that's why the term 'fast breeder' is used). The plutonium-239 produced is also used to produce nuclear weapons.

Nuclear waste

A big advantage of nuclear reactors over coal- and gas-fired power plants is that they do not generate large quantities of the greenhouse gas, carbon dioxide. However, the used fuel rods in a nuclear reactor are radioactive and contain a mixture of radioisotopes.

Some of the waste radioisotopes have half-lives of only minutes, while others have half-lives of thousands of years. These waste products are currently sealed in steel containers or glass blocks and stored in power stations or buried deep at sea or underground away from groundwater. However, there is still no permanent solution to the problem of disposing of nuclear waste.

It has been suggested that nuclear waste should be sent by rocket to the Sun or into outer space. However, the risk of a rocket carrying nuclear waste exploding before leaving the Earth's atmosphere makes that solution very risky.

FIGURE 6.15 A worker inspecting output at a nuclear power plant

6.4.3 Radiotherapy in medicine

The treatment of cancer

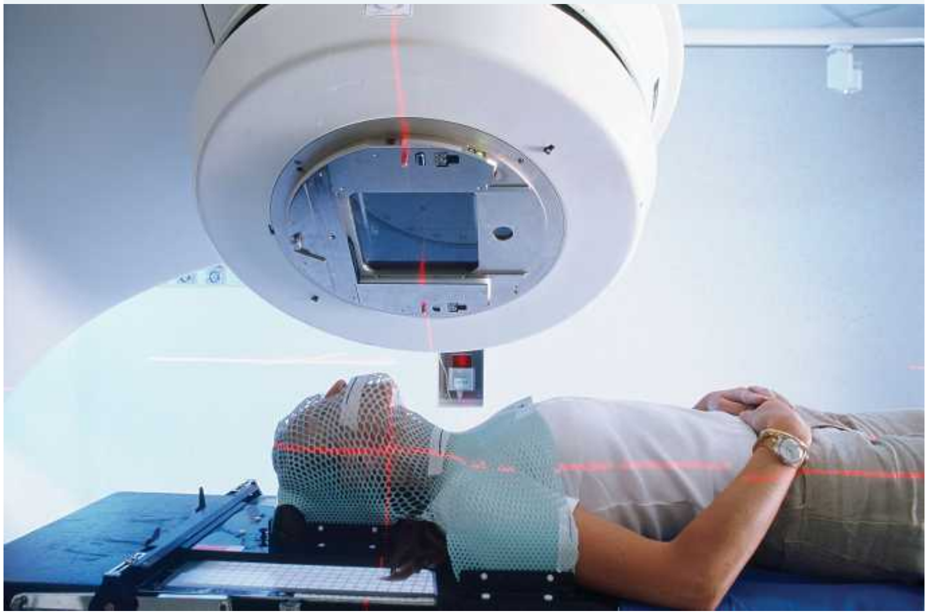
Radiotherapy is the use of radioisotopes, or other radiation such as x-rays, to kill cancer cells or prevent them from multiplying. Cancer cells tend to grow very quickly, and a bit like someone running downhill, are slightly out of control and can be tripped up. Normal cells are also damaged by the radiation but tend not to be as badly affected. Radiation can also be targeted at a small area so that surrounding tissue is not damaged. Radiotherapy is often used along with other treatments such as surgery, use of drugs, and harnessing the immune system (immunotherapy).

Radiation can be directed at the cancer by a machine like the one in figure 6.16. This method is known as **external radiotherapy**. The other method, known as **internal radiotherapy** or brachytherapy, involves placing radioisotopes inside the body at or near the site of the cancer. In some cases, both methods are used. The type of treatment depends on the type of cancer, its size and its location as well as the general health of the patient.

external radiotherapy cancer treatment where radiation is directed from an external machine to the site of the cancer

internal radiotherapy cancer treatment also known as brachytherapy. Radioisotopes are placed inside the body at, or near, the site of a cancer.

FIGURE 6.16 A patient receiving external radiotherapy treatment



The diagnosis of disease

Radioactive substances may be inserted into the body to detect or identify the cause of disease. The radiation produced by the substance while it is in the part of the body under investigation is measured to diagnose the problem (table 6.4).

Some radioisotopes can be used to obtain images of parts of the body. The gamma rays emitted by these radioisotopes are used to produce the images. PET (positron emission tomography) scans use cameras surrounding the patient to detect gamma rays coming from radioisotopes injected into the body (figure 6.17).

FIGURE 6.17 A PET image of the human brain

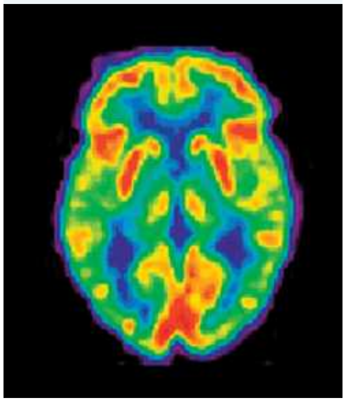


TABLE 6.4 Some of the radioisotopes used in the treatment and diagnosis of disease

Radioisotope	Use	Half-life
Barium-137	Diagnosis of digestive illnesses	2.6 minutes
Iodine-123	Monitoring of thyroid and adrenal glands, and assessment of damage caused by strokes	13 hours
Thallium-201	Detection of damaged heart muscles	3 days
Iodine-131	Diagnosis and treatment of thyroid problems	8 days
Phosphorus-32	Treatment of leukaemia	14.3 days
Iron-59	Measurement of blood flow and volume	46 days
Cobalt-60	Used in radiotherapy for treating cancer	5 years

on Resources

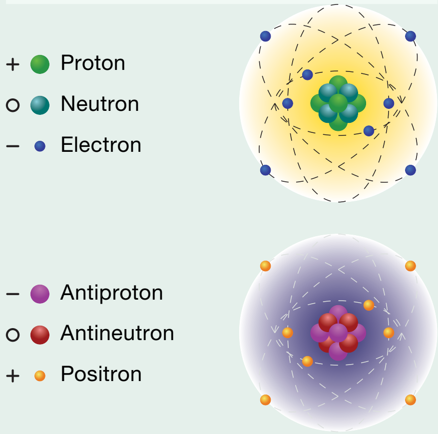
Video eLesson Nuclear medicine (eles-1084)

EXTENSION: Matter and antimatter atoms

As you know, PET detects gamma radiation emitted from radioisotopes that have been inserted into the body. However, the radioisotopes used in PET scans first emit a **positron**, which is like an electron but with a positive charge. This is antimatter, which is like the matter that makes up our universe, but the protons and electrons have the *opposite charge,* i.e. positrons are positively charged electrons and antiprotons are negatively charged protons.

Antimatter is very unstable as it is annihilated when it encounters its opposite matter particle, releasing gamma radiation. It is this gamma radiation that is detected in PET, when an emitted positron encounters an electron.

FIGURE 6.18 Atoms of matter and antimatter



6.4.4 Preserving food

If you've ever suffered from food poisoning, you will understand why it is necessary to keep food from spoiling. Food in sealed containers can be preserved by exposing it to gamma radiation. The radiation kills the micro-organisms in the food and keeps it from spoiling.

positron a particle emitted during PET, which is like an electron but with a positive charge

elog-0152

INVESTIGATION 6.2

Radioactive decay

Aim

To investigate the decay of a radioisotope used as a medical treatment

Materials

- graph paper or a graphing program, for example, Excel

Method

The half-life of the radioisotope iodine-131 is 8 days.

1. Calculate the mass of iodine-131 left after 8, 16, 24, 32, 40, 48, 56, 64, 72 and 80 days if 100 g is given to a patient to treat a thyroid problem.

Results

1. Present the results of your calculations in a table.
2. Choose an appropriate graph to show how the radioisotope decays. Represent time on the horizontal axis and the mass of the iodine-131 sample on the vertical axis.

Discussion

1. What fraction of the iodine-131 is left after:
   a. 8 days **b.** 16 days **c.** 24 days **d.** 80 days?
2. Why is it difficult to store radioisotopes with short half-lives?

Conclusion

Write a conclusion to this investigation as a response to the aim.

on Resources

eWorkbook — Putting nuclear energy to use (ewbk-3140)

assess on — Additional automatically marked question sets

6.4 Exercise

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To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. MC What is the name of the nuclear reaction that takes place in nuclear power stations?
   A. Radiation B. Nuclear fusion C. Nuclear fission D. Emission
2. Describe three uses of radioactive elements.
3. a. What is radiotherapy?
   b. How does it prevent the spread of cancer through the body?
4. MC How do radioisotopes used in food preservation stop food from spoiling?
   A. Increases the microbial fighting properties of the food
   B. Creates a protective layer on the inside of the can
   C. Microbes that cause food spoilage are killed by radiation
   D. None of the above. Radiation is dangerous to health

Apply and analyse

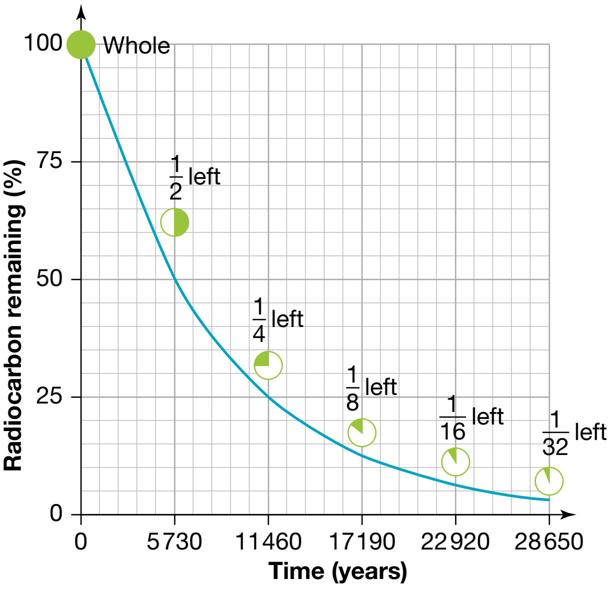
5. Explain whether carbon-14 dating can be used for fossils that are millions of years old.

   Use table 6.4 to answer questions 6-8.

6. Identify whether iodine-131 is a more stable radioisotope than barium-137. Justify your answer.

Evaluate and create

7. The use of barium-137 in the diagnosis of digestive illnesses involves the patient drinking it in a syrup. What property of barium-137 makes its use quite safe?
8. Identify an isotope best suited to use in external radiotherapy. Justify your answer.
9. SIS Use the graph to answer the following questions.
   a. Parts of the skeleton of a large animal are found buried in sand dunes. The amount of radioactive carbon-14 in the bones is about one-eighth of that found in the skeletons of living animals. How long ago did the animal probably die (to the nearest thousand years)?



b. What approximate percentage of the original amount of radioactive carbon-14 would you expect to find in:
   i. a spear 11 000 years old
   ii. a skull 23 000 years old, found in a cave?

Fully worked solutions and sample responses are available in your digital formats.

6.5 The dark side of radiation

LEARNING INTENTION

At the end of this subtopic you will be able to describe the health effects of radiation exposure, examples of nuclear reactor disasters (including why they occurred and the effects), and the short- and long-term impacts of nuclear weapons.

6.5.1 Advantages and disadvantages of radiation

While nuclear radiation has many uses that are beneficial to society as a whole, there is no doubt that it is very much a double-edged sword.

TABLE 6.5 Advantages and disadvantages of radioisotopes

Advantages of radioisotopes	Disadvantages of radioisotopes
Radiometric dating	Nuclear weapons
Medical treatment	Nuclear disasters at power plants
Medical diagnosis	Nuclear waste from industry and medicine
Power generation	Contamination of ecosystems
Food preservation	Radiation sickness
Smoke detectors	Chronic diseases, for example, cancer
Scientific research	Mutations and birth defects

Disasters at nuclear power plants and the events of World War II are large-scale reminders of the dangers of radioisotopes. While the devastating power of nuclear weapons are obvious, the effects of nuclear radiation on cells can be more insidious. Nuclear radiation damages molecules in cells, particularly DNA, leading to many adverse health effects.

- Exposure can have immediate effects including nausea, headaches, vomiting and diarrhoea, collectively termed **radiation sickness**.
- Over longer timeframes, exposure can lead to diseases such as cancer and immune system collapse later in life.
- **Mutations** in sperm and eggs can be passed from parents to children, leading to birth defects and other diseases.

radiation sickness immediate symptoms of exposure to damaging nuclear radiation

mutation damage to DNA in cells, which can be passed on to children through sperm and eggs

EXTENSION: Deaths caused by radiation

Radiation has caused the death of some remarkable people.

- Alexander Litvinenko was an ex-Russian secret service officer who had fled to the United Kingdom. He unexpectedly fell ill in November 2006 and died in hospital only a few weeks later. It is alleged that he was poisoned with polonium-210 placed in a pot of tea.
- It is a sad irony that Marie Curie (the woman who developed the theory of radioactivity and discovered the radioactive elements radium and polonium) herself died of leukaemia at the age of 67. Her illness was almost certainly caused by her constant exposure to radioactivity.

FIGURE 6.19 Marie Curie

6.5.2 When reactors go wrong

SCIENCE AS A HUMAN ENDEAVOUR: Nuclear disasters

Chernobyl, 1986

Like any other piece of complex technology, a nuclear reactor can work safely only if its many individual systems are functioning smoothly and efficiently. They must be well-maintained and well-managed by highly - trained personnel. Unfortunately, in many cases the flaws of a nuclear reactor's design are not spotted until it is too late.

The Chernobyl Power Complex is located about 130 km from Kyiv, the capital of Ukraine. At the time of the disaster in 1986, Ukraine was part of the Soviet Union. The accident at Chernobyl was due to a combination of old technology and an operator error. Reactor 4 had three main design flaws:

- graphite control rods that can become unstable
- water coolant that can be vaporised at high temperatures
- no radiation containment shield allowing radiation to escape from a damaged reactor.

The story began on 25 April 1986, when reactor 4 was scheduled to be shut down for routine maintenance. The events leading to the nuclear meltdown are summarised in figure 6.20.

While only two people were killed in the original explosion, three others died during the night and 50 emergency workers died from acute radiation poisoning. Since the accident, the rate of thyroid cancer in children has been ten times higher in the region around Chernobyl and, of the 600 000 people contaminated by radiation, 4000 have died from long-term cancers.

FIGURE 6.20 The meltdown in reactor 4 of the Chernobyl Power Complex

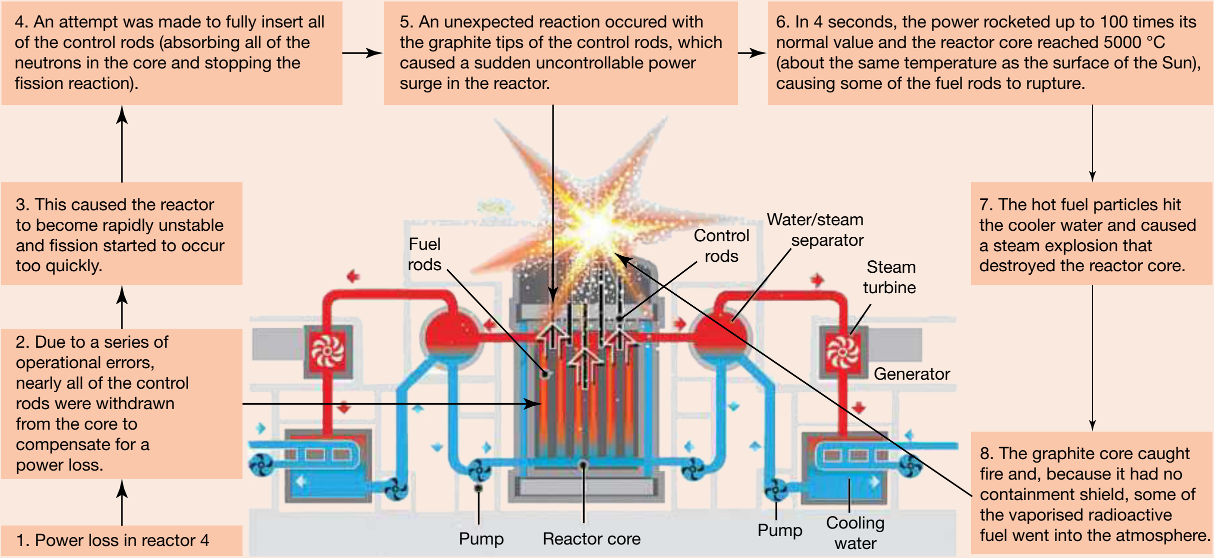


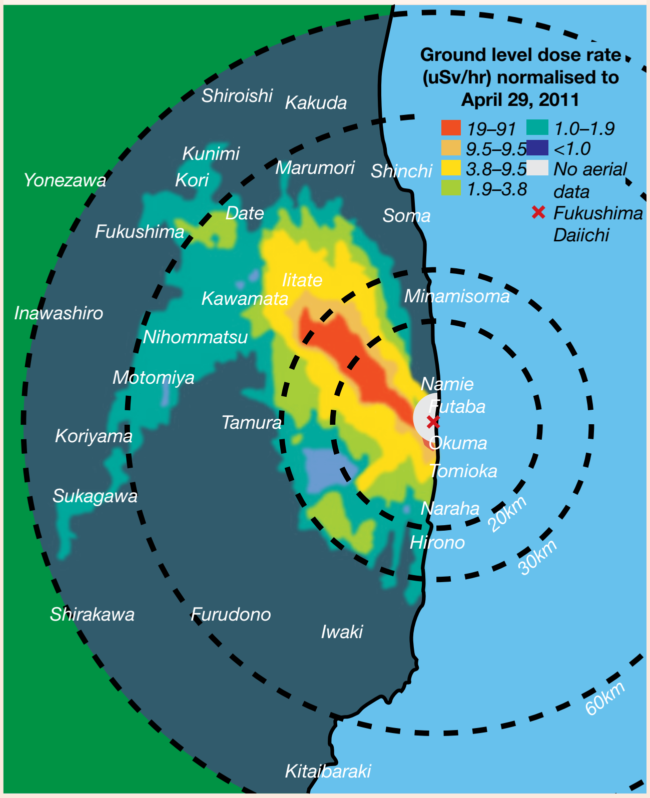
FIGURE 6.21 Pripyat in the Ukraine was home to 50 000 people, most of whom had jobs at Chernobyl. **a.** When reactor 4 of the Chernobyl nuclear power plant exploded, the town was abandoned. **b.** Now nature is starting to reclaim it despite the remaining radiation.

Fukushima, 2011

The Fukushima Daiichi nuclear disaster was caused by a series of unlucky events occurring one after another.

1. On 11 March 2011, a massive earthquake occurred off the coast of Honshu (the largest island of Japan) leaving the Fukushima nuclear reactor complex relatively unharmed but reliant on its back-up generators.
2. Unfortunately, the earthquake caused a tsunami that struck the coast of Honshu less than an hour later, killing more than 19 000 people and destroying over 1 000 000 buildings.
3. The reactors at Fukushima Daiichi were flooded by the 15 m high tsunami, disabling 12 of the 13 back-up generators as well as the heat exchangers that released waste heat into the sea.
4. Without power, the circulation of water coolant around the reactor cores ceased, causing them to become so hot that much of the coolant water was boiled off.
5. The heat became high enough to melt the fuel rods in reactors 1, 2 and 3 (this is referred to as a **meltdown**).
6. A reaction between the cladding of the melted fuel rods and the remaining coolant water produced hydrogen gas that exploded when mixed with the air.
7. This threw nuclear material up into the atmosphere.

FIGURE 6.22 Map showing the amount of radiation absorbed per hour at ground level around Fukushima, 6 weeks after the meltdown



More than 160 000 people had to be evacuated from the area for fear of radiation. While three employees at the Daiichi plants were killed directly by the earthquake and tsunami, there were no fatalities from the nuclear accident.

on Resources

Video eLesson The abandoned nuclear reactor 4 at Chernobyl (eles-2660)

meltdown the melting of a nuclear-reactor core as a result of a serious nuclear accident

6.5.3 Nuclear weapons

SCIENCE AS A HUMAN ENDEAVOUR: Effects of nuclear weapons

There are approximately 13 500 nuclear weapons in the world today, enough to destroy our planet many times over and effectively obliterate life.

The devastating effects of nuclear weapons on buildings and living organisms are due to a series of events that occur in order. When nuclear weapons are detonated:

1. Enormous amounts of heat and radiation spread out from the centre of the blast (known as **ground zero**) in what is called a **thermal flash**.
2. This radiation forms a fireball that generates the distinctive mushroom cloud associated with nuclear weapons. The radiation from the Hiroshima bomb formed a fireball 7 km across. At locations close to ground zero, most substances were melted or burned and organic matter (including people) was vaporised. People up to 50 km away received serious burns and those who looked directly at the flash were blinded.
3. After the initial blast, the vaporisation of particles close to the blast causes an implosion of air from further out.
4. When these inrushing air particles collide, they cause a high-pressure shock wave to spread outwards at speeds of up to 3000 km/h. This shock wave causes the destruction of buildings, blowing them outwards from the centre of the blast.
5. The blast also releases large amounts of radiation in the form of gamma rays, which can burn out electrical and electronic systems including computer networks and power grids, and even disrupt the electrical systems that control cars, planes and weaponry. This burst of energy is called an **electromagnetic pulse**.
6. The most devastating effects for survivors are due to radiation exposure. The radioactive nuclei formed during the nuclear reactions as well as tonnes of irradiated dust are blasted high into the atmosphere during detonation and the formation of the mushroom cloud.
7. In the weeks following the nuclear explosion, these come back down to Earth as **nuclear fallout**. This radioactive fallout increases the background radiation for many years where it comes down, so people in the fallout zones are exposed to higher radiation levels with damaging effects.

ground zero the centre of a nuclear weapon blast

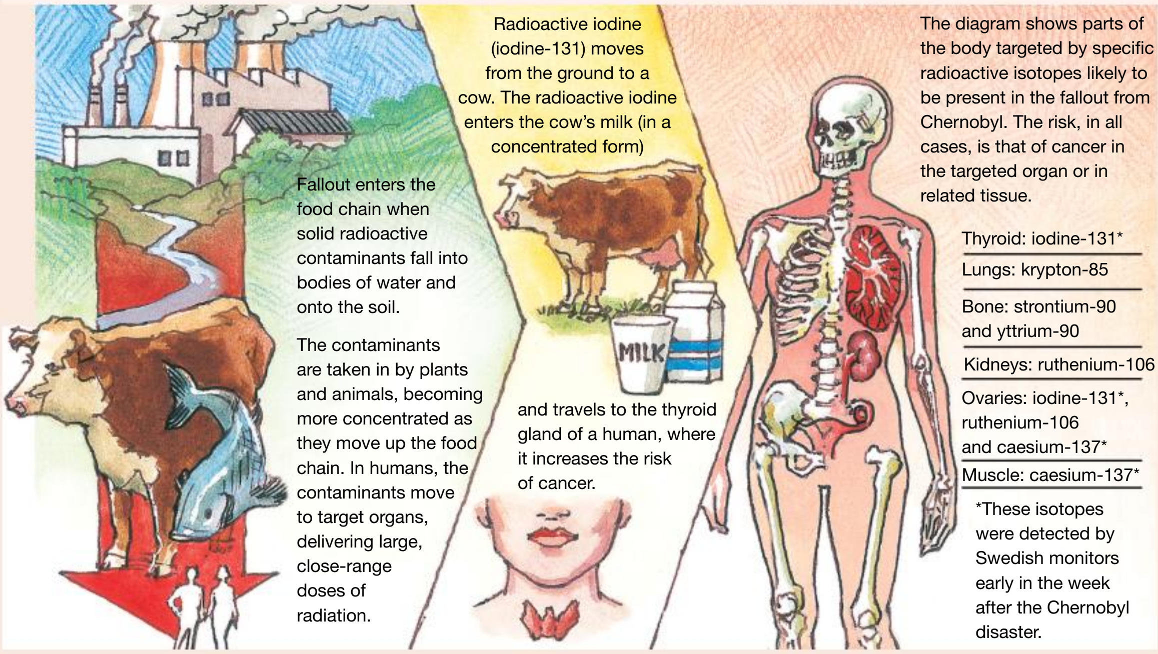
thermal flash enormous amounts of heat and radiation that spread out from the centre of a nuclear blast

electromagnetic pulse a burst of electromagnetic activity caused by the detonation of nuclear devices

nuclear fallout irradiated dust blasted high into the atmosphere during detonation and the formation of the mushroom cloud. In the weeks following the nuclear explosion, these come back down to Earth as nuclear fallout.

FIGURE 6.23 Atomic bomb destruction, Hiroshima, Japan. Around 90 per cent of the buildings were destroyed, with only a few concrete-reinforced buildings surviving. Some 70 000 people died instantly, with tens of thousands more dying in the aftermath.

FIGURE 6.24 The devastating impacts of nuclear fallout



6.5 Exercise

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Select your pathway

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

Remember and understand

1. What is radioactive fallout and why is it given this name?
2. List one effect of exposure to large doses of nuclear radiation to humans:
   a. immediately after exposure
   b. after a longer amount of time.
3. Define the following terms:
   a. meltdown
   b. thermal flash
   c. electromagnetic pulse
   d. ground zero.
4. Two natural disasters led to the meltdown in reactors 1, 2 and 3 at the power station in Fukushima.
   a. Identify the two natural disasters.
   b. Describe how each disaster affected the power plant.
   c. Identify two consequences of these events on the power plant.

Apply and analyse

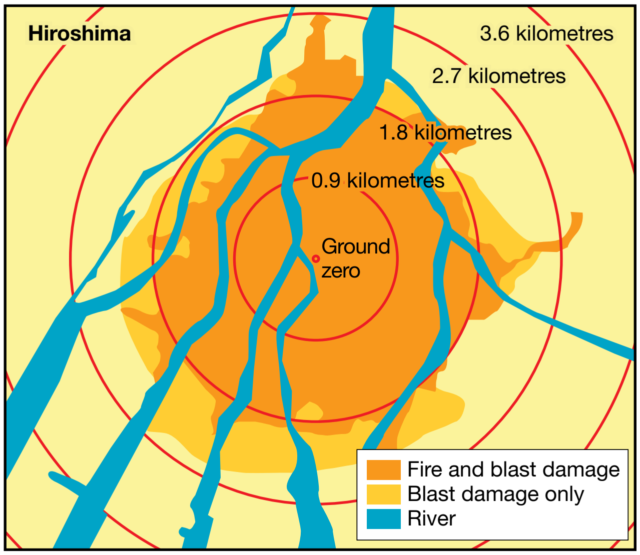
5. Identify one design flaw of reactor 4 at Chernobyl and explain how it contributed to the disaster.
6. 'The ability of nuclear radiation to kill cells is both an advantage and a disadvantage.' Do you agree or disagree with this statement? Justify your answer.

Evaluate and create

7. **SIS** The following table and map indicate the distribution of deaths and injuries caused by the Hiroshima bombing in 1945.

TABLE Distribution of deaths and injuries, Hiroshima bombing (1945)

Distance from ground zero (km)	Killed	Injured	Initial population
0–1.0	26 700 (86%)	3000 (10%)	31 200
1.0–2.5	39 600 (27%)	53 000 (37%)	144 800
2.5–5.0	1700 (2%)	20 000 (25%)	80 300



Atomic bomb damage of Hiroshima

a. Use this information to determine:

i. the original population of Hiroshima (within 5 km of ground zero) before the bombing
ii. the number of people killed who were within 1 km of ground zero
iii. the number of people who were unharmed despite being within 1 km of ground zero.

b. As you would expect, the number of people killed gets smaller the further from ground zero that they were located. What explanations can you give that the percentage wounded doesn't follow the same pattern?

Fully worked solutions and sample responses are available in your digital formats.

6.6 Thinking tools — Concept maps and plus, minus, interesting charts

6.6.1 Tell me

What is a concept map?

A concept map is a diagram that is useful for showing what you understand about a particular topic. It helps you arrange a larger topic of complex ideas by classifying them into smaller and smaller ideas. It explains the relationships between parts or elements with statements on the links between them. A concept map is also called a knowledge map or a concept web.

What is a plus, minus, interesting chart?

A plus, minus, interesting (PMI) chart also groups a topic into ideas, but these groups are based on your perspective of the topic — that is, do you find the ideas a positive, a negative, or just an interesting aspect?

FIGURE 6.25 A concept map

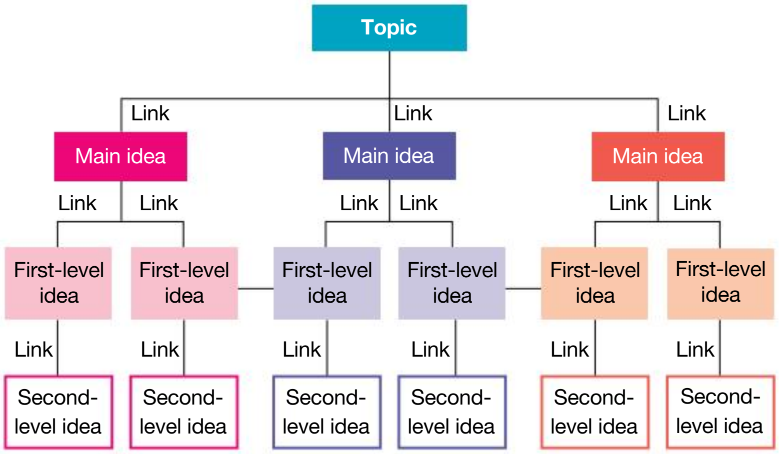
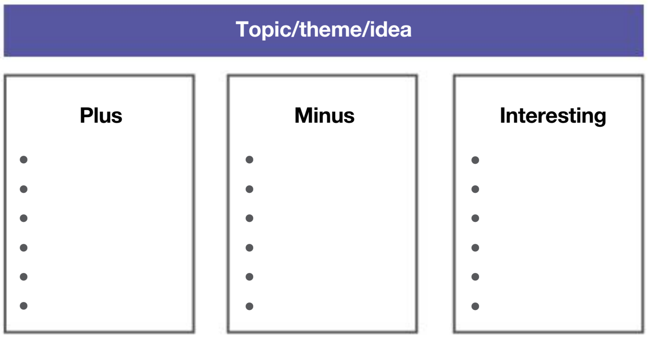


FIGURE 6.26 A PMI chart

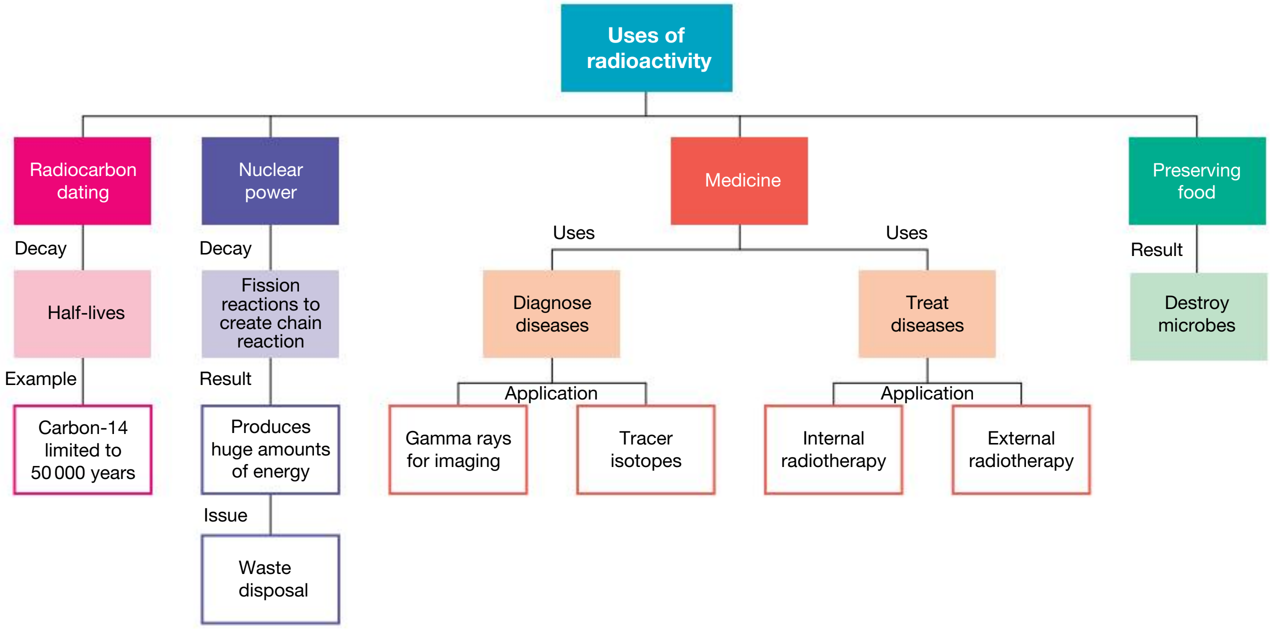


6.6.2 Show me

To create a concept map:

1. Choose a topic that has a number of different parts or ideas. Write any ideas you may have onto small pieces of paper. For example, you might choose to consider how radioactivity can be used by humans.
2. Examine your pieces of paper and put your ideas into your concept map, which looks like this:

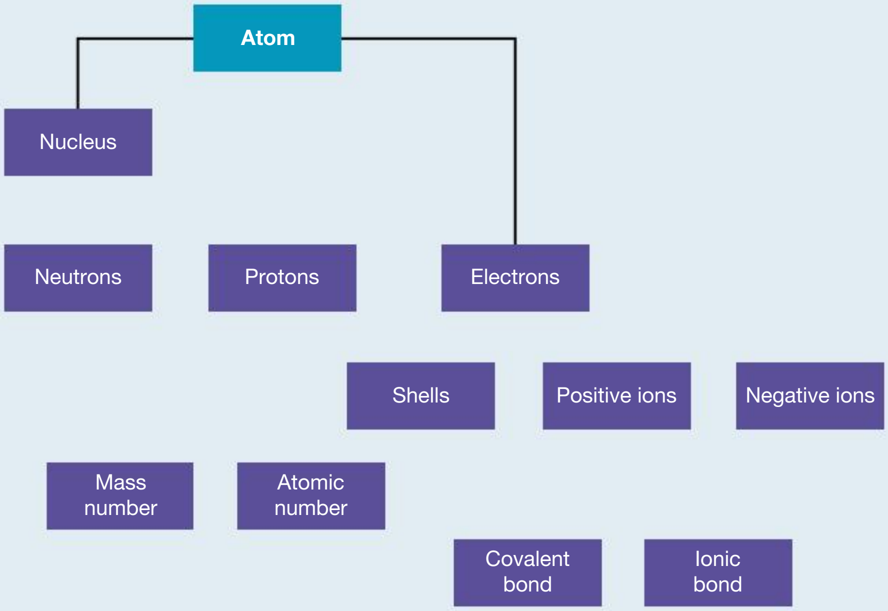
FIGURE 6.27 A concept map of the uses of radioactivity



6.6.3 Let me do it

6.6 ACTIVITIES

1. A concept map can be used to illustrate some of the important ideas associated with the atom and the links between the ideas.
   a. Copy the concept map below into your workbook and complete it by adding the links between the ideas.



   b. Construct your own concept map to show how ideas about what is inside substances are linked. For example, you may choose to consider what is inside a molecule of carbon dioxide, or you may choose another substance. Begin by working in a group to brainstorm the main ideas of the topic.
2. Construct a concept map of ideas associated with radioactivity.
3. Create a PMI chart on radioactivity, using the diagram below as a starting point.

Radioactivity		
Plus	**Minus**	**Interesting**
• Can be used to treat cancer	• Radioactive isotopes can be used in nuclear weapons	• Radioactivity was discovered by accident
•	•	•
•	•	•
•	•	•
•	•	•
•		
•		

Fully worked solutions and sample responses are available in your digital formats.

6.7 Review

Access your topic review eWorkbooks

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-3142	ewbk-3144	ewbk-3146

on Resources

6.7.1 Summary

Chemical building blocks

- Atoms are so small we rely on scientific models to help us understand them.
- Models are based on repeated experiments and observations and help us make predictions and to explain observed phenomena.
- New discoveries mean models are improved over time.
- The model of the atom has evolved from the J. J. Thomson's plum pudding model.
- The current model of the atom consists of a tiny dense nucleus, composed of positive protons and neutral neutrons, surrounded by a cloud of tiny negative electrons.
- A neutral atom has an equal number of protons (+) and electrons (–).

Stability and change — Inside the nucleus

- Atoms of the same element have the same number of protons in their nucleus.
- Atoms of the same element can have different numbers of neutrons in their nucleus. This gives the atoms different masses, and these are called isotopes.
- Nuclide notation is used to represent different atoms and their isotopes.
- ${}^{A}_{Z}X$: where X is the chemical symbol of the element, A is the mass number (number of protons and neutrons in the nucleus) and Z is the atomic number (the number of protons in the nucleus).
- For different isotopes of the same element, the mass number (A) changes, as it is the number of protons and neutrons in the nucleus. Hydrogen has three isotopes: ${}^{1}_{1}H$, ${}^{2}_{1}H$, ${}^{3}_{1}H$.
- Atoms can be stable or unstable.
- In unstable atoms, the neutrons and protons in the nucleus are not held together as strongly, and decay to form other elements. These are radioisotopes.
- Natural radioactivity is emitted without any energy needing to be supplied.
- The energy emitted by radioactive substances is nuclear radiation. There are three types:
  - Alpha particles (α): a positively charged helium nuclei. They cannot travel through materials easily.
  - Beta particles (β): can be positive or negative and are the same size and mass as an electron. They travel near the speed of light and can penetrate human skin.
  - Gamma rays (γ): bursts of energy released after alpha or beta particles emitted. They at the speed of light and are highly penetrating.
- The half-life of a radioisotope is the time taken for half of all the nuclei in a sample of a radioisotope to disintegrate or decay.
- Background radiation comes from naturally - occurring radioactive substances and a small amount from cosmic radiation.

Using radioactivity

- Radiometric dating uses the known half-lives of radioactive elements. For example, radiocarbon dating can be used to date archaeological samples. Older samples, such as very old rocks, are dated using the decay of uranium to lead.

- Uranium is used in nuclear reactors as fuel rods. The uranium is bombarded with neutrons and undergoes a fission reaction that breaks the uranium into smaller atoms and simultaneously releases a huge amount of energy. This energy is used to make steam to turn turbines and generate electricity.
- Nuclear power does not generate large amounts of greenhouse gases, but does produce radioactive waste, which is difficult to dispose of safely.
- Radioisotopes are used to treat disease through internal or external radiotherapy.
- Radioisotopes can be used to diagnose disease through the use of radioactive tracers.
- Radioisotopes can be used to preserve food by destroying the microbes in the food.

The dark side of radiation

- Disasters at nuclear powerplants include Chernobyl (1986) and Fukushima (2011).
- Nuclear weapons use the energy released in nuclear reactions to generate huge blasts of energy and chemical fallout, which can kill and injure thousands of people simultaneously.
- Radiation from nuclear meltdowns and fallout causes long-term diseases and birth defects to thousands of people.

6.7.2 Key terms

alpha particles positively charged nuclei of helium atoms, consisting of two protons and two neutrons
beta particles charged particles (positive or negative) with the same size and mass as electrons
cosmic radiation naturally occurring background radiation from outer space
decay to transform into a more stable particle
electromagnetic pulse a burst of electromagnetic activity caused by the detonation of nuclear devices
electrons extremely light (1800 times lighter than protons and neutrons) negatively charged particles inside an atom. Electrons orbit the nucleus of an atom.
external radiotherapy cancer treatment where radiation is directed from an external machine to the site of the cancer
fission splitting of the nuclei of large atoms into two smaller atoms and several neutrons, releasing radiation and heat energy
fuel rods one of the rods that form the fuel source of a nuclear reactor; contains the fissile nuclides needed to produce a nuclear chain reaction
gamma rays high-energy electromagnetic radiation produced from some radioactive decay; the radiation has no mass and travels at the speed of light
ground zero the centre of a nuclear weapon blast
half-life time taken for half the radioactive atoms in a sample to decay — that is, change into atoms of a different element
internal radiotherapy cancer treatment also known as brachytherapy. Radioisotopes are placed inside the body at, or near, the site of a cancer.
isotopes atoms of the same element that differ in the number of neutrons in the nucleus
meltdown the melting of a nuclear-reactor core as a result of a serious nuclear accident
mutation damage to DNA in cells, which can be passed on to children through sperm and eggs
neutrons tiny particles found in the nucleus of an atom. Neutrons have no electrical charge and the same mass as a proton.
nuclear fallout irradiated dust blasted high into the atmosphere during detonation and the formation of the mushroom cloud. In the weeks following the nuclear explosion, these come back down to Earth as nuclear fallout.
nuclear radiation radiation from the nucleus of an atom, consisting of alpha or beta particles, or gamma rays
nuclear reactors power plants where the radioactive properties of uranium are used to generate electricity
nucleus central part of an atom, made up of protons and neutrons; plural = nuclei
nuclide a type of atom characterised by the number of protons and the number of neutrons in its nucleus
positron a particle emitted during PET, which is like an electron but with a positive charge
protons tiny particles found in the nucleus of an atom. Protons have a positive electrical charge and the same mass as a neutron
radiation sickness immediate symptoms of exposure to damaging nuclear radiation
radiocarbon dating a method of determining the age of a fossil using the remaining amount of unchanged radioactive carbon

radioisotope a radioactive form of an isotope
radiometric dating determining the ages of rocks and fossils based on the rate of decay or half-life of particular isotopes
stable a nucleus that does not change spontaneously. The protons and neutrons in the nucleus are held together strongly.
thermal flash enormous amounts of heat and radiation that spread out from the centre of a nuclear blast
unstable an atom in which the neutrons and protons in the nucleus are not held together strongly

on Resources

eWorkbooks	Study checklist (ewbk-3148) Literacy builder (ewbk-3149) Crossword (ewbk-3151) Word search (ewbk-3153)
Practical investigation eLogbook	Topic 6 Practical investigation eLogbook (elog-0154)
Digital document	Key terms glossary (doc-34774)

6.7 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Which of the particles in a neutral atom has:
   a. a negative electric charge
   b. a positive electric charge
   c. no electric charge
   d. the smallest mass?
2. Describe the contributions of the following scientists to our understanding of the structure of the atom.
   a. J. J. Thomson
   b. Lord Rutherford
   c. Niels Bohr
3. Which type of nuclear radiation travels at the speed of light?
4. The hydrogen atom exists as three different isotopes.
   a. How are the atoms of each isotope different from the others?
   b. Identify two features of the hydrogen atom that are the same for each of the three isotopes.
5. Where does most of the natural background radiation that we experience every day come from?

Apply and analyse

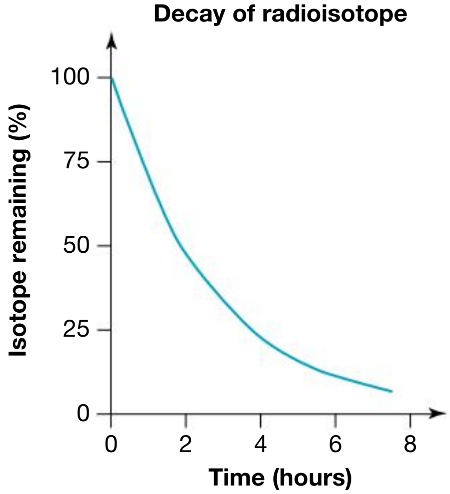
6. The diagram represents a model of a neutral atom.
   a. Which two particles make up the nucleus of the atom?
   b. Which particles are shown orbiting the nucleus in the atom?
   c. To which element does this atom belong?
7. Alpha particles are helium nuclei containing two protons and two neutrons.
   a. What is the electric charge of an alpha particle?
   b. How does the mass of an alpha particle compare with the mass of a beta particle?

a. Suggest why alpha particles are easily stopped by human skin while beta particles are not.
b. Which type of radiation from the nucleus is more penetrating than either alpha or beta particles?

8. Radioisotopes have many uses.
   a. What property of radioisotopes makes them useful?
   b. Describe three of the beneficial uses of radioisotopes.
   c. Some radioisotopes are considered highly dangerous even after thousands of years. Why?
9. Two isotopes of the element carbon found naturally on Earth are carbon-12 and carbon-14.
   a. How is every atom of carbon-14 different from every atom of carbon-12?
   b. What features and properties do carbon-14 and carbon-12 have in common?
   c. Which of the two carbon isotopes is stable?
10. The half-life of strontium-90 is 28 years. If a 400 gram sample of strontium-90 was left to decay, how many grams of the sample would be left after:
    a. 28 years b. 56 years c. 84 years?

Evaluate and create

11. Estimate the half-life of the isotope whose decay is shown in the graph.



12. **SIS** Explain how it is possible to use carbon-14 to estimate the age of the remains of a dead plant embedded in a rock.

Fully worked solutions and sample responses are available in your digital formats.

on Resources

eWorkbook Reflection (ewbk-3038)

teachon

Test maker
Create customised assessments from our extensive range of questions, including teacher-quarantined questions.
Access the assignments section in learnON to begin creating and assigning assessments to students.

RESOURCE SUMMARY

on Resources

Below is a full list of **rich resources** available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

6.1 Overview

eWorkbooks
- Topic 6 eWorkbook (ewbk-3130)
- Student learning matrix (ewbk-3129)
- Starter activity (ewbk-3132)

Practical investigation eLogbook
- Topic 6 Practical investigation eLogbook (elog-0154)

Video eLesson
- The experiments that led to our understanding of the atom (eles-1780)

6.2 Chemical building blocks

eWorkbooks
- Chemical building blocks (ewbk-3134)
- How big is an atom? (ewbk-3136)

Practical investigation eLogbook
- Investigation 6.1: Exploring models of the atom (elog-0150)
- A model of an oxygen atom (eles-2657)

6.3 Stability and change — inside the nucleus

eWorkbook
- Top ten elements (ewbk-3138)

Video eLessons
- Deuterium (eles-2658)
- Smashing atoms in CERN (eles-1085)

Interactivity
- Radioactive half-life (int-1652)

6.4 Using radioactivity

eWorkbook
- Putting nuclear energy to use (ewbk-3140)

Practical investigation eLogbook
- Investigation 6.2: Radioactive decay (elog-0152)

Video eLessons
- The mystery of radium (eles-1779)
- A nuclear fission chain reaction (eles-2659)
- Nuclear medicine (eles-1084)

6.5 The dark side of radiation

Video eLesson
- The abandoned nuclear reactor 4 at Chernobyl (eles-2660)

6.7 Review

eWorkbooks
- Topic review Level 1 (ewbk-3142)
- Topic review Level 2 (ewbk-3144)
- Topic review Level 3 (ewbk-3146)
- Study checklist (ewbk-3148)
- Literacy builder (ewbk-3149)
- Crossword (ewbk-3151)
- Word search (ewbk-3153)
- Reflection (ewbk-3038)

Practical investigation eLogbook
- Topic 6 Practical investigation eLogbook (elog-0154)

Digital document
- Key terms glossary (doc-34774)

To access these online resources, log on to **www.jacplus.com.au**.

7 Chemical reactions

LEARNING SEQUENCE

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7.9 Review 460

7.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

7.1.1 Introduction

Every single living thing on Earth depends on chemical reactions — from the largest mammal, the blue whale, right down to the smallest insects. This reaction is known as respiration and it transforms the sugars in food and oxygen into carbon dioxide, water and the energy all living things need to survive. While respiration makes carbon dioxide and water, in plants chemical reactions transform carbon dioxide and water into sugars and other nutrients such as proteins and starch. This process is known as photosynthesis.

FIGURE 7.1 Sometimes it is easy to know if a chemical reaction is taking place.

In this topic we will investigate chemical reactions. We will learn how to recognise when a chemical reaction has taken place, and how the atoms in the reactants rearrange to form the products of the reaction. We will learn the importance of the energy stored in the products and the reactants and whether a reaction will produce heat or need heat for it to occur. There are many different types of chemical reactions, and they are used in all aspects of our lives. We will look at reactions between acids and bases, between acids and metals and the combustion reactions that drive our world. Combustion reactions occur in the burning of fuels to generate electricity, operate industry and transportation, and keep our homes at a comfortable temperature. The pollution generated by burning fuels can cause other chemical reactions that damage our environment. Chemical reactions are also used to treat injuries and save lives.

on Resources

Video eLesson A strong acid is poured into a solution containing glucose (eles-2584)

When acid is added to a glucose solution a series of colour changes can be observed, which shows a chemical reaction has taken place.

7.1.2 Think about chemical reactions

1. How do atoms behave during chemical reactions?
2. In chemical reactions, what is conserved other than energy?
3. How does an icepack go cold without containing anything cold?
4. What makes an airbag inflate during a car accident?
5. How can you stop your stomach from aching and rumbling?
6. What causes tooth decay?
7. What is pickling and why is it done?
8. Why does acid rain dissolve statues?
9. What is the active ingredient of petrol?
10. Which combustion reaction takes place in your own body?

7.1.3 Science inquiry

The chemistry of eating

Preparing, eating and digesting food all involve chemical reactions, many of which you already know about. Answer the following questions to find out what you already know about these important chemical reactions.

1. a. What happens when you drink lots of fizzy pop? How does your stomach feel?
   b. Why do you think your stomach feels like that?
   c. Can you relate this to the chemistry occurring in your stomach?
2. You may have experienced indigestion or acid reflex.
   a. Which type of substance is contained in the products that can be taken to reduce the discomfort and pain caused by the extra acid?
   b. What is the name of this chemical reaction that provides relief from the effects of the extra acid?

elog-0099

INVESTIGATION 7.1

Cleaning up with baking soda and vinegar

Aim

To observe the chemical reaction between baking soda and vinegar and to investigate the cleaning properties of the reaction

Materials

- 100 mL white vinegar
- 1 tablespoon of baking soda or baking powder
- rubber gloves
- a small cleaning brush or scourer
- a dirty beaker, cup or vessel
- access to a basin or sink

The cleaning products on the right can be replaced by two simple ingredients that do the same tasks.

Method

1. Place the dirty vessel in the sink or basin.
2. Add 100 mL of vinegar to the vessel.
3. Carefully add the baking soda or baking powder to the vinegar.
4. Use the brush or scourer to clean the vessel.
5. Rinse the vessel with water.

Results

What did you observe when you added the baking soda (or powder) to the vinegar in the dirty vessel?

Discussion

1. Describe the reaction when the baking soda or powder was added to the vinegar.
2. What do you think caused this reaction?
3. Describe the cleaning effect of the reaction.

Conclusion

What can you conclude about the cleaning properties of the reaction between baking soda and vinegar?

on Resources

eWorkbooks	Topic 7 eWorkbook (ewbk-3012) Student learning matrix (ewbk-3097) Starter activity (ewbk-3014)
Practical investigation eLogbook	Topic 7 Practical investigation eLogbook (elog-0097)
learnon	Access and answer an online pre-test and receive **immediate corrective feedback** and **fully worked solutions** for all questions.

7.2 Rearranging atoms and molecules

LEARNING INTENTION

At the end of this subtopic you will be able to describe the difference between reactants and products, the Law of Conservation of Mass and the Law of Constant Proportions.

7.2.1 Chemical reaction

A cake rising in an oven, a bath bomb fizzing in a full bathtub, and an old car getting rusty — what do they have in common? They are all evidence of chemical reactions.

Chemical reactions take place when the bonds between atoms are broken and new bonds are formed, creating a new arrangement of atoms and at least one new substance. As the new substance is formed, observable changes take place — a change in temperature or colour, the formation of a visible gas or new solid, or perhaps even just an odour.

7.2.2 Reactants and products

The new substances that are formed during a chemical reaction are called the **products**. The original substances are called the **reactants**.

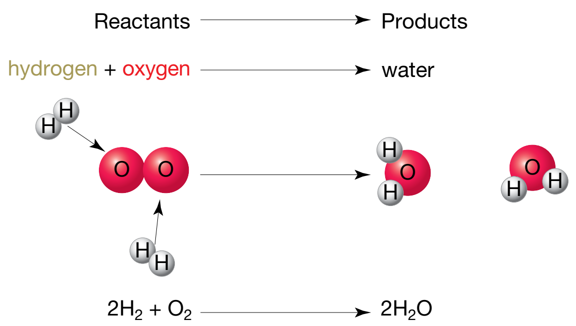
For example, when hydrogen gas is added to oxygen gas and ignited, the new substance water is formed. The reactants are hydrogen and oxygen. The product is water. The bonds between the hydrogen atoms and oxygen atoms are broken and new bonds are formed between oxygen and hydrogen, as shown in figure 7.2.

products chemical substances that result from a chemical reaction

reactants the original substances present in a chemical reaction

Notice that the hydrogen and oxygen atoms that were present in the reactants are also present in the product. There is no gain or loss of atoms. They have been rearranged to form new products. Recall that molecules can be made up of all the same atoms, as in hydrogen and oxygen or as a combination of different atoms as in water.

FIGURE 7.2 The reaction between the reactants hydrogen and oxygen to create the product water



ACTIVITY: Making models

Use a molecular modeling kit or some plasticine and toothpicks to make a model of the reaction between hydrogen and oxygen. If you are using a modelling kit, you will need four white atoms to model the hydrogen atoms, and to join them together in two lots of two. You will also need two red oxygen atoms joined together. Now rearrange the atoms to form two molecules of water as in figure 7.2.

7.2.3 Conservation of mass

The idea of atoms rearranging themselves may seem obvious now, but two hundred years ago it was not. It was thought, for example, that when a candle burned the wax simply vanished. In other words, it was thought that matter could disappear.

In the eighteenth century, French nobleman Antoine-Laurent Lavoisier showed that although a candle seems to disappear as it burns, there is as much mass present after it has completely burned as there was before. The apparent loss of mass was caused by gases moving into the atmosphere.

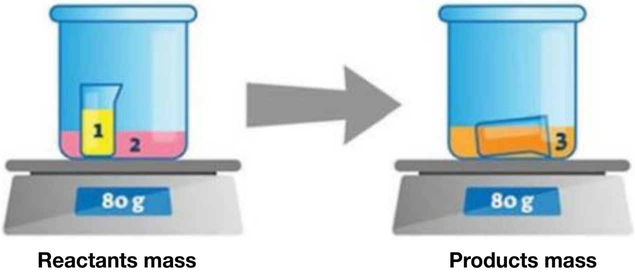
FIGURE 7.3 The conservation of mass

During most ordinary chemical reactions or physical changes:
- the mass of the products equals the mass of the reactants
- no matter is lost or gained.

Lavoisier's ideas led to the development of the **Law of Conservation of Mass**, which states that matter can be neither created nor destroyed during a chemical reaction. Figures 7.3 and 7.4 are simple representations of the Law of Conservation of Mass.

Law of Conservation of Mass in a chemical reaction, the total mass of the reactants is the same as the total mass of the products

FIGURE 7.4 The mass of the reactants is the same as the mass of the products.



Lavoisier also provided evidence for the **Law of Constant Proportions**, which states that a compound, no matter how it is formed, always contains the same relative amounts of each element. For example, carbon dioxide (CO_2) always contains the same relative amounts of carbon and oxygen (about 27 per cent of the mass is made up of carbon). It does not matter whether the carbon dioxide forms from the reaction of sherbet in your mouth or from the reaction in the engine of a car, this proportion is fixed because every molecule of CO_2 is formed by the bonding of one carbon atom with two oxygen atoms. This law helped to shape our understanding of the way atoms bond together. In fact, after his unfortunate execution during the French Revolution, Lavoisier became known as the Father of Modern Chemistry.

Law of Constant Proportions in chemical compounds, the ratio of the elements is always the same

on Resources

Video eLesson Priestley and the Law of Conservation of Mass (eles-1767)

elog-0101

INVESTIGATION 7.2

Conserving mass

Aim

To compare the mass of the products of a chemical reaction with the mass of its reactants

Materials

- safety glasses
- 250 mL conical flask
- 4 Alka-Seltzer tablets
- 1 balloon
- matches
- an electronic balance
- 100 mL measuring cylinder
- water

Method

CAUTION

Wear safety glasses.

Part A:

1. Place the conical flask on the balance and pour in 100 mL of water.
2. Place two tablets alongside the conical flask and record the total mass.
3. Remove the flask from the balance and drop the tablets into the water.
4. When the reaction is complete, weigh the flask and record the mass.

Part B:

5. Rinse out the flask thoroughly and again add 100 mL of water.
6. Place two tablets inside the balloon. You may need to break the tablets into pieces to do this.
7. Stretch the neck of the balloon over the conical flask, being careful not to drop the tablets into the water. The balloon should be flopped over, resting against the side of the flask.
8. Place the conical flask and balloon onto the balance and record the total mass.
9. Lift up the top of the balloon and drop the tablets into the water in the conical flask.
10. When the reaction is complete, weigh the flask and record the mass. Do not remove the balloon.
11. After you have recorded the mass, remove the balloon. Light a match and test the gas in the conical flask. Record your observations

Results

TABLE Results of Part A, Investigation 7.2	
Mass of conical flask and 100 mL water	
Mass of conical flask, 100 mL water and two antacid tablets before reaction	
Mass of conical flask, 100 mL water and two antacid tablets after reaction	

TABLE Results of Part B, Investigation 7.2	
Mass of conical flask, 100 mL water, balloon and two antacid tablets before reaction	
Mass of conical flask, 100 mL water, balloon and two antacid tablets after reaction	

What did you observe in the gas test with the lit match?

Discussion

1. Which gas do you think filled the balloon and the conical flask?
2. Comment on your results of the total mass before and after each reaction. Explain your answer.
3. Antacid tablets can be taken to relieve indigestion. Why do we sometimes burp after taking antacid tablets?
4. Why do you think it took a long time for the Law of Conservation of Mass to be developed?
5. What improvements would you make to this experiment?

Conclusion

Write a conclusion outlining your findings when you compared the mass of the products with the mass of the reactants in the reaction.

on Resources

assesson Additional automatically marked question sets

7.2 Exercise

learnon

To answer questions online and to receive immediate feedback and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Fill in the blanks to complete the sentence.
   In a chemical reaction the chemicals that react in a reaction are called ____________ and the chemicals that are formed in a chemical reaction are called _______________ .

2. Atoms in substances are rearranged after chemical reactions. True or false? Explain.
3. Fill in the blanks to complete the sentence.
   Identify the second product produced by the chemical reaction.
   sodium sulfate + barium chloride → barium sulfate + ____________.
4. What does the Law of Conservation of Mass state?
5. Fill in the blanks to complete the sentence.
   The Law of Constant Proportions states that a compound, no matter how it forms, always contains the ____________ amounts of each element; atoms in compounds always combine in whole number ratios.

Apply and analyse

6. **SIS** A piece of paper is weighed on an accurate balance and then burned, leaving a pile of ashes. The ashes are collected and weighed on the same balance.
   a. Would you expect the mass of the ashes to be the same as the mass of the paper before it was burned?
   b. Explain your answer in terms of the products produced.
7. **SIS** Explain why, when a piece of steel wool burns, the mass of the blackened material is greater than the original mass of the steel wool.
8. **SIS** Read through Investigation 7.2 (you may have already conducted this investigation). Predict the results of the experiment if the balloon was to be left off the conical flask from step 2 of the experiment.

Evaluate and create

9. Find out more about Antoine-Laurent Lavoisier, his work and why he was killed by guillotine during the French Revolution.

Fully worked solutions and sample responses are available in your digital formats.

7.3 Chemical reactions and energy

LEARNING INTENTION

At the end of this subtopic you will understand the difference between endothermic and exothermic reactions.

7.3.1 Starting a chemical reaction

Simply placing two chemicals together does not always mean they will react. For example, hydrogen and oxygen react violently, yet a mixture of these two gases can be stored indefinitely if kept cool in a secure container. Energy must be supplied to start the reaction. Sometimes only a small amount of energy is needed to start (or initiate) the reaction. Heat transferred from the surroundings may be enough.

Energy may also be supplied by an electric current, a beam of light or a Bunsen burner flame. This energy is needed to begin the process of breaking the bonds in the reactants, which allows the atoms to rearrange and form new bonds in the products.

Energy must be supplied to start the reaction between hydrogen and oxygen. This is shown by the word 'heat' over the reaction arrow.

$$\text{hydrogen} + \text{oxygen} \xrightarrow{\text{heat}} \text{water}$$

$$2H_2 + O_2 \xrightarrow{\text{heat}} 2H_2O$$

7.3.2 Energy and chemical reactions

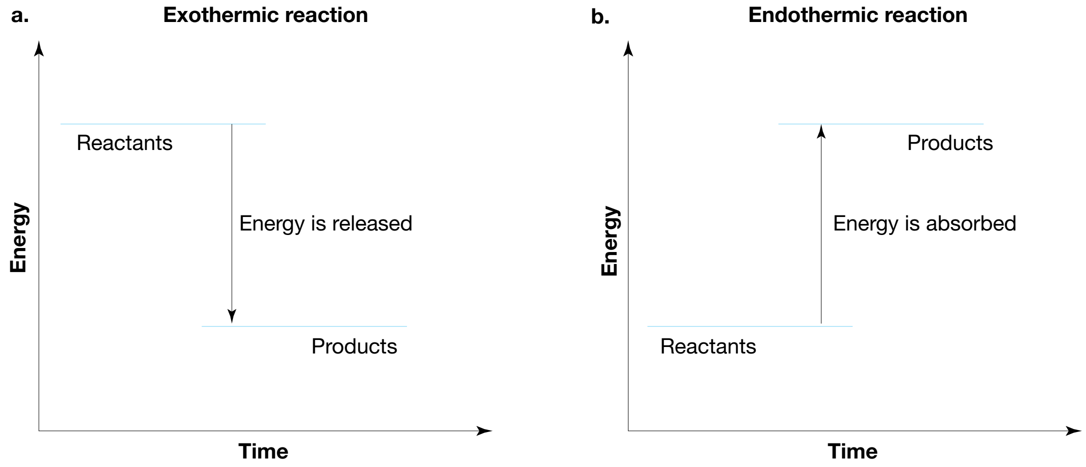
When fuels such as petrol are burned in motor vehicles, energy is released and used to keep the vehicle in motion. Burning is a chemical reaction in which fuel reacts with oxygen, producing carbon dioxide, water and several other products.

The energy released comes from the rearrangement of atoms. There is less energy stored in the chemical bonds in the products than there was in the reactants. Chemical reactions that release energy are called **exothermic** reactions (figure 7.6a).

Chemical reactions in which energy is absorbed from the surroundings are called **endothermic** reactions. There is more energy 'stored' in the chemical bonds of the products than there was in the reactants (figure 7.6b).

FIGURE 7.5 The energy that keeps this motorcycle moving comes from an exothermic chemical reaction.

FIGURE 7.6 a. Exothermic reactions release energy. **b.** Endothermic reactions absorb energy.

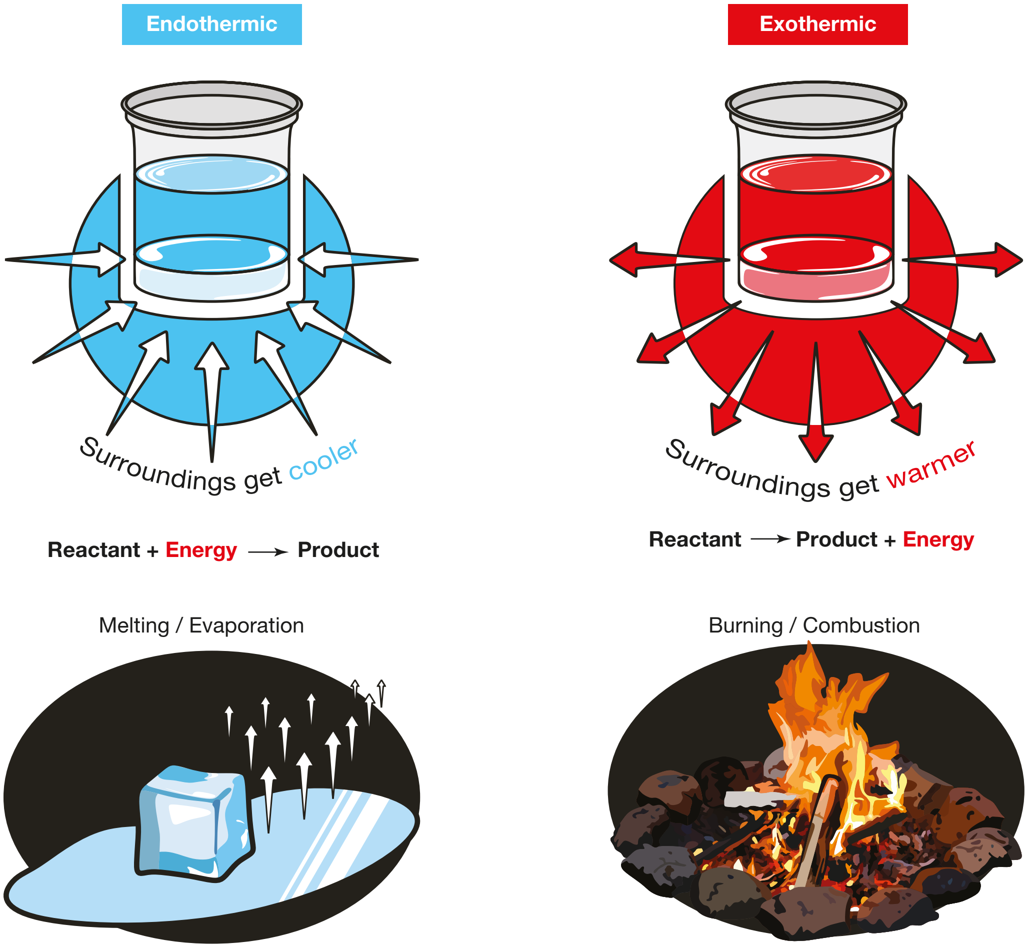


Whether energy is absorbed or released during a chemical reaction can be observed by comparing the temperature of the substance before the reaction with their temperature after the reaction.

exothermic chemical reactions that give out heat energy to the surroundings

endothermic chemical reactions that absorb heat energy from the surroundings

FIGURE 7.7 Endothermic and exothermic reactions



WHAT DOES IT MEAN?

The words exothermic and endothermic come from the Greek words *exo*, meaning 'out', *endo*, meaning 'in', and *therme*, meaning 'heat'.

7.3.3 Exothermic reactions

Portable hand warmers, commonly used by skiers and campers, become hot when shaken due to an exothermic chemical reaction in which energy is released to the surroundings. One type of hand warmer contains iron, water, salt and sawdust. When the contents of the packet are shaken quickly, the powdered iron reacts with oxygen to form iron oxide. During this chemical reaction, some of the **chemical energy** of the substances is transformed into heat energy which is transferred to the hands, increasing their temperature. We can show this chemical reaction with a word equation.

chemical energy energy stored in chemical bonds that is released during chemical reactions

Exothermic reactions produce heat.

For example: iron + oxygen → iron oxide + heat

7.3.4 Endothermic reactions and processes

Athletes use instant icepacks to treat injuries. The icepack may consist of a plastic bag containing ammonium nitrate or ammonium chloride powder and an inner bag of water. Squeezing the bag breaks the weaker inner bag and immediately causes the powder to dissolve in the water. The **chemical process** that takes place absorbs energy from the injured area, thus lowering its temperature. It is therefore an endothermic chemical *process*. It is not an endothermic chemical *reaction* as the ammonium nitrate can be recovered from the water, by reversing the process.

We can describe this chemical process with a word equation.

FIGURE 7.8 Endothermic reactions can be used to treat injuries.

Endothermic processes and reactions absorb energy.

For example: ammonium chloride + water → ammonium chloride in solution

chemical process changes the arrangement of the atoms or molecules of the substances involved

elog-0103

INVESTIGATION 7.3

Exothermic and endothermic processes

Note: Part A is teacher demonstration only.

Aim

To investigate some exothermic and endothermic processes

Materials

- safety glasses
- bench mat
- 4 large test tubes and test-tube rack
- 10 mL measuring cylinder
- Balance
- thermometer (–10 °C to 110 °C)
- stirring rod
- magnesium ribbon
- sandpaper
- 0.5 M hydrochloric acid
- lithium chloride
- sodium thiosulfate
- potassium chloride
- spatula

Method

Part A: Magnesium in hydrochloric acid

1. Pour 10 mL of 0.5 M hydrochloric acid into a test tube in a test-tube rack. Place a thermometer in the test tube and allow it to come to a constant temperature. Record the temperature of the solution.
2. Clean a 10 cm piece of magnesium ribbon using the sandpaper until it is shiny on both sides. Coil the magnesium ribbon and place it into the test tube of hydrochloric acid.
3. Observe the temperature of the solution as the magnesium reacts with the hydrochloric acid and record the final temperature of this solution.

Part B: Lithium chloride in water

4. Pour 10 mL of water into a test tube in a test-tube rack. Place a thermometer in the water in the test tube and allow it to come to a constant temperature. Record the temperature of the water.
5. Use a balance to weigh 2 g of lithium chloride, add it to the water in the test tube and stir gently.
6. Observe the temperature of the solution as the lithium chloride dissolves in the water and record the final temperature of this solution.

Part C: Sodium thiosulfate in water

7. Using a new test tube, repeat part B using 2 g of sodium thiosulfate instead of lithium chloride.

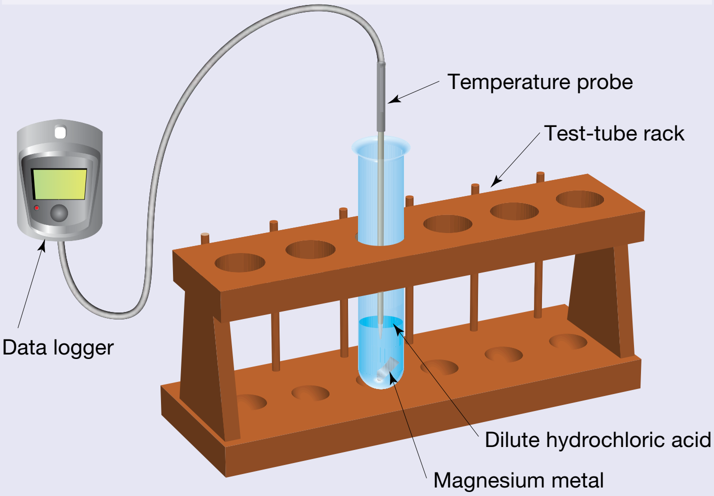
Part D: Potassium chloride in water

8. Using a new test tube, repeat part B using 2 g of potassium chloride instead of lithium chloride.

Results

Construct a table like the one provided to record the temperature changes as the four chemical processes described take place. Complete the table by calculating the change in temperature resulting from each process. Use + or – signs to indicate whether the temperature decreased or increased.

A data logger can be used to record the temperature changes in this investigation.



Results of investigation 7.3

Chemical process	Initial temperature (°C)	Final temperature (°C)	Change in temperature (°C)
Part A			
Part B			
Part C			
Part D			

Discussion

1. Which processes were exothermic and which were endothermic?
2. Which one or more of the chemical processes above was a chemical reaction? How do you know?

Conclusion

What can you conclude from the temperature changes you observed?

SCIENCE AS A HUMAN ENDEAVOUR: Airbags

Airbags have saved many people from death or serious injury in car accidents. When an airbag inflates, it creates a cushion between the occupant's body and the windscreen, dashboard and other parts of the inside of the car. Airbags, which are made from nylon, may be concealed in the steering wheel, dashboard, doors or seats.

The rapid inflation of an airbag is the result of an explosive exothermic chemical reaction. The reaction is triggered by an electronic device in the car that detects any sudden change in speed or direction of the car. The bag fills with a harmless gas. When the occupants move forwards or sideways into the bag, they push the gas out of the airbag through tiny holes in the nylon. The airbag is usually totally deflated by the time the car comes to rest.

FIGURE 7.9 Airbags inflate as a result of an explosive chemical reaction.

One of the chemical reactions commonly used in airbags produces a massive burst of nitrogen gas. In some airbags, the nitrogen is released when the toxic chemical sodium azide (NaN_3) decomposes:

$$\text{sodium azide} \rightarrow \text{sodium} + \text{nitrogen gas}$$
$$2NaN_3 \rightarrow 2Na + 3N_2$$

Other chemicals, including potassium nitrate, were present to react with the potentially dangerous sodium metal that was produced. In newer airbags, sodium azide has been replaced with less toxic (and less expensive) chemicals.

SCIENCE AS A HUMAN ENDEAVOUR: Alfred Noble — An explosive career

Alfred Nobel is probably most famous for bequeathing his fortune to establish the Nobel Prizes in Physics, Chemistry, Medicine, Literature and Peace. However, Nobel made his fortune inventing **dynamite** and developing the use of explosives in the 1860s.

FIGURE 7.10 Alfred Nobel bequeathed his fortune to establish the Nobel Prizes.

Alfred Nobel was born in Sweden in 1833. He was educated in Russia. Nobel was fluent in several languages and interested in literature, poetry, chemistry and physics. In Paris he met a young Italian chemist, Ascanio Sobrero, who had earlier invented nitroglycerine, a highly explosive liquid. Alfred Nobel became very interested in nitroglycerine and saw its potential in the construction industry. When he returned to Stockholm in Sweden he tried to develop nitroglycerine as an explosive. Several explosions, including one in 1864 in which Nobel's younger brother was killed, made the authorities realise that nitroglycerine was extremely dangerous.

Alfred Nobel had to move his laboratory out of Stockholm's city limits and onto a barge anchored on a nearby lake. He was determined to make nitroglycerine safe to work with. He discovered that mixing nitroglycerine with silica would turn the liquid into a paste that could be shaped into rods suitable for inserting into drilling holes. In 1866 he patented this material under the name dynamite.

FIGURE 7.11 Dynamite is used in the mining industry

Dynamite is mainly used in the mining and construction industries. Huge areas of rock can be broken apart because the chemical reaction involved in dynamite's explosion releases large amounts of energy and gas, which can exert great pressure. Explosives can release enough energy to cause a small earthquake. One of the largest non-nuclear explosions ever was the Texas City disaster that occurred on April 16, 1947, and it was the deadliest industrial accident in U.S. history (figure 7.12). A fire started on board a ship docked in the port, the *SS Grandcamp*, which detonated approximately 2100 metric tons of ammonium nitrate. The explosion then triggered explosions on other ships and in an oil refinery nearby.

The invention of dynamite could not have come at a better time than the middle of the nineteenth century. New mines were being opened to supply coal for heating and steam engines, iron and other building materials. Railways were being laid all over the world and passes had to be blasted through the mountains. Over the years, Alfred Nobel set up factories and laboratories in more than 20 countries.

dynamite relatively stable explosive invented by Alfred Nobel in 1866. It is created by mixing nitroglycerine with an absorbent substance such as silica, forming a paste that can be shaped into rods.

Alfred Nobel died in 1896 and when his will was opened it came as a surprise that the interest earned by his $9 million fortune was to be used for the establishment of the Nobel Prizes. The prizes were to be awarded 'for the good of humanity' in the fields of chemistry, physics, physiology or medicine, literature and peace.

FIGURE 7.12 The Texas City disaster in 1947

on Resources

eWorkbook	Exothermic and endothermic reactions (ewbk-3016)
Video eLesson	An explosion in a quarry (eles-2587)
assess on	Additional automatically marked question sets

7.3 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. MC Energy can be required to start a reaction. Select three possible sources of this energy.
   A. Electricity
   B. Ice
   C. A flame
   D. Wind
   E. Heat from a beam of light
2. Fill in the blanks to complete the sentence.
   How are exothermic reactions different from endothermic reactions? An exothermic process is one in which ___________. Examples include the ___________or the reaction of hydrochloric acid and magnesium. An endothermic process is one in which ___________. An example is ___________.
3. MC In a chemical reaction in which energy is absorbed from the surroundings, where does the extra energy go?
   A. It disappears
   B. Into the chemical bonds of the products
   C. The surrounding air
   D. To the space between the bonds of the products
4. MC An endothermic process:
   A. releases energy into the surroundings but can be reversed
   B. absorbs energy from the surroundings but can be reversed
   C. is a chemical reaction that cannot be reversed
   D. is not a chemical and cannot be reversed.

5. Explain why the chemical process that takes place in an icepack containing ammonium chloride is not a chemical reaction.
6. Write a word equation to describe one chemical reaction that occurs to inflate an airbag.
7. MC What was Alfred Nobel's most famous invention?
   A. Nitroglycerine
   B. Airbags
   C. Dynamite
   D. Sodium azide

Apply and analyse

8. Create a flowchart of four steps to describe how an explosive is able to split large volumes of rock using some of the following options.
   a. Release small amounts of energy and gas
   b. Release large amounts of energy and gas
   c. Breaks apart huge areas of rock
   d. A chemical reaction involved in dynamite's explosion
   e. The pressure exerted
   f. The energy escalates to create more gas.
9. Determine if the chemical reactions described below are exothermic or endothermic?
   a. Dilute hydrochloric acid is added to dilute sodium hydroxide in a test tube. They react to produce sodium chloride and water. After the reaction, the test tube feels very warm.
   b. As garden compost decomposes, the compost heap gets warmer.
   c. Barium hydroxide and ammonium thiosulfate solutions are mixed and the temperature drops enough to freeze water.
10. SIS Instant hot compresses are used by athletes to warm torn muscles. They relieve pain and speed up the healing process. The hot compresses contain calcium chloride powder and an inner bag of water. When the inner bag bursts, the calcium chloride dissolves in the water and releases energy.
   a. Is the chemical process that takes place in the compress endothermic or exothermic?
   b. How does the energy stored in the chemical bonds of the product compare with the energy stored in the chemical bonds of the calcium chloride and water?
   c. Write a word equation to describe this chemical process.
   __________powder → _____________solution
11. Explosions are exothermic reactions. True or false? Explain.
12. SIS Read through Investigation 7.3 (you may have already completed some or all of this investigation). Predict the change in temperature of one of the processes if twice the amount of reactants were added. Give a reason for your answer.

Evaluate and create

13. Suggest why Alfred Nobel donated his entire fortune to reward those who worked for the 'good of humanity'?
14. SIS The winners of Nobel Prizes are referred to as laureates. The Nobel Prizes are announced in October of each year.
   Choose one Australian scientist who has won the Nobel Prize and write a short biography about him or her. Include in your biography information on when they were awarded the Nobel Prize and the work that they did to receive such a prestigious award.

Fully worked solutions and sample responses are available in your digital formats.

7.4 Acids and bases

LEARNING INTENTION

At the end of this subtopic you will be able to describe the features of acids and bases and the role they have in our everyday life.

7.4.1 Acids and bases

Chemical reactions involving acids and bases play an important role in our lives. They occur in the kitchen, in the laundry, in the garden, in swimming pools and even inside the body.

Acids

Acids are **corrosive** substances. That means they react with solid substances, 'eating' them away. Acids have a sour taste and some acids, such as the sulfuric acid used in car batteries, are dangerously corrosive. The acids in ant stings and bee stings cause pain. Others, such as the acids in fruits and vinegar, are safe — even pleasant — to taste.

Acids can be strong or weak. Strong acids are able to react to their full extent with other substances, while weak acids do not.

- Strong acids include hydrochloric acid (HCl), sulfuric acid (H_2SO_4) and nitric acid (HNO_3)
- Weak acids include ethanoic acid (CH_3COOH), carbonic acid (H_2CO_3) and phosphoric acid (H_3PO_4).

WHAT DOES IT MEAN?

The word *acid* comes from the Latin word *acidus*, meaning 'sour'.

Bases

Bases have a bitter taste and feel slippery or soapy to touch. Some bases are very corrosive, especially caustic soda (sodium hydroxide). Caustic soda will break down fat, hair and vegetable matter and is the main ingredient in drain cleaners. Other bases are used in soap, shampoo, toothpaste, dishwashing liquid and cloudy ammonia as cleaning agents. Bases that can be dissolved in water are called **alkalis**.

Like acids, bases can be strong or weak. Strong bases also are able to react to their full extent with other substances, while weak bases do not. The strength of an acid or base is measured by the pH scale (see below).

- Strong bases include potassium hydroxide (KOH), sodium hydroxide ($NaOH$) and barium hydroxide ($Ba(OH)_2$).
- Weak bases include ammonia (NH_3), calcium carbonate ($CaCO_3$) and sodium carbonate (Na_2CO_3).

acids chemicals that react with a base to produce a salt and water; edible acids taste sour

corrosive a chemical that wears away the surface of substances, especially metals

bases chemical substances that will react with an acid to produce a salt and water; edible bases taste bitter

alkalis bases that dissolve in water

7.4.2 Indicators

Acid–base **indicators** are substances that can be used to tell whether a substance is an acid or a base. The indicators react with acids and bases, producing different colours in each. Some indicators are made from natural food dyes and some vegetables; for example, red cabbage can be used as a pH indicator. Two commonly used indicators are litmus (figure 7.13), which turns red in an acid and blue in a base, and bromothymol blue, which turns yellow when added to an acid and a bluish-purple when added to a base.

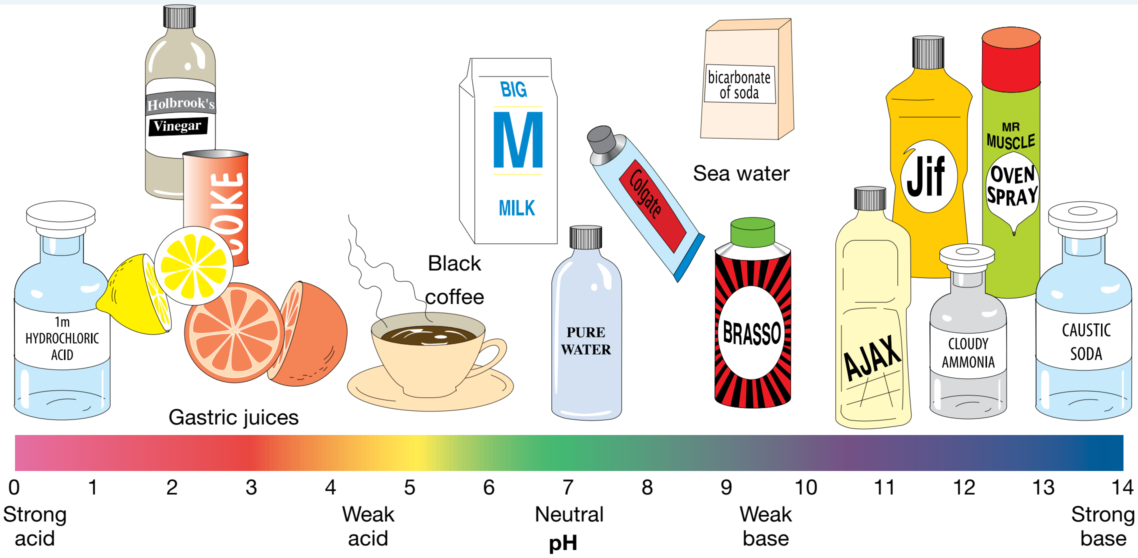
FIGURE 7.13 Litmus paper contains an indicator that turns blue when dipped into a basic solution.

The pH scale

You can describe how acidic or basic a substance is by using the numbers on the **pH scale**. The pH scale ranges from 0 to 14.

- Low pH numbers (less than pH 7) mean that substances are acidic.
- High pH numbers (more than pH 7) mean that substances are basic.
- If a substance has a pH of 7, it is said to be neutral — neither acidic nor basic. This is shown on the pH scale in figure 7.14.

FIGURE 7.14 The pH values of some common substances



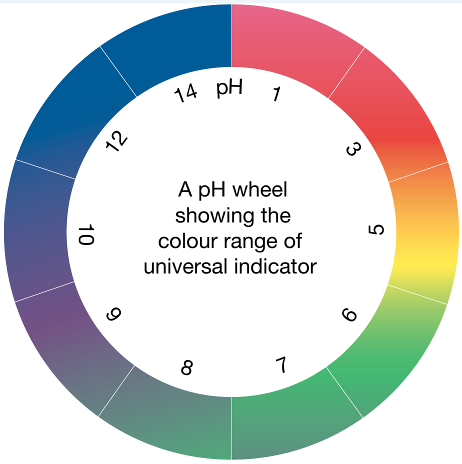
The pH scale measures whether an acid or base is strong or weak. For example, a strong acid has a very low pH (pH 0 or 1) and a strong base has a very high pH (pH 13 or 14). The pH of a substance can be measured using a pH meter or a special indicator called **universal indicator**. Universal indicator is a mixture of indicators and it changes colour as the strength of an acid or base changes. The colour range of universal indicator is shown in figure 7.15.

indicator a substance that changes colour when it reacts with acids or bases; the colour shows how acidic or basic a substance is

pH scale the scale from 1 (acidic) to 14 (basic) that measures how acidic or basic a substance is

universal indicator a mixture of indicators that changes colour as the strength of an acid or base changes, indicating the pH of the substance

FIGURE 7.15 The colour range of universal indicator. It is pink in strong acid (pH 1), blue in strong base (pH 14) and green in neutral solutions (pH 7).



Resources

Video eLesson Universal indicator solution (eles-2304)

Interactivity pH rainbow (int-0101)

7.4.3 Neutralisation

When an acid and a base react with each other, the products include water and a salt. Such a reaction is called a **neutralisation** reaction. These reactions can be very useful. They can relieve pain caused by indigestion or the stings from wasps, bees and ants. They can be used to change the pH of soil to make it more suitable for growing particular plants. Neutralisation reactions are also used in cooking and to keep swimming pools and spas clean.

neutralisation a reaction between an acid and a base. A salt and water (a neutral liquid) are the products of this type of reaction

To neutralise means to stop something from having an effect. To stop the properties of acids from having an effect, a base can be added to it. Similarly, to stop a base from having an effect, an acid can be added.

A neutralisation reaction occurs when an acid and a base react.

The products are water and a salt.

acid + base → water + salt

For example:

hydrochloric acid + sodium hydroxide → water + sodium chloride

$$HCl + NaOH \rightarrow H_2O + NaCl$$

Sometimes, a gas is produced as well as a salt and water.

For example:

hydrochloric acid + sodium bicarbonate → water + sodium chloride + carbon dioxide

$$HCl + NaHCO_3 \rightarrow H_2O + NaCl + CO_2$$

EXTENSION: Strength versus concentration

We have seen that acids and bases can be strong or weak. A strong acid or base completely separates into their ions in water. This means they can react to their full extent in water.

For example, hydrochloric acid (HCl) is a strong acid, and sodium hydroxide (NaOH) is a strong base.

$$HCl \rightarrow H^+ + Cl^-$$
$$NaOH \rightarrow Na^+ + OH^-$$

Weak acids and bases only partially separate in water, and so they cannot react to their full extent.

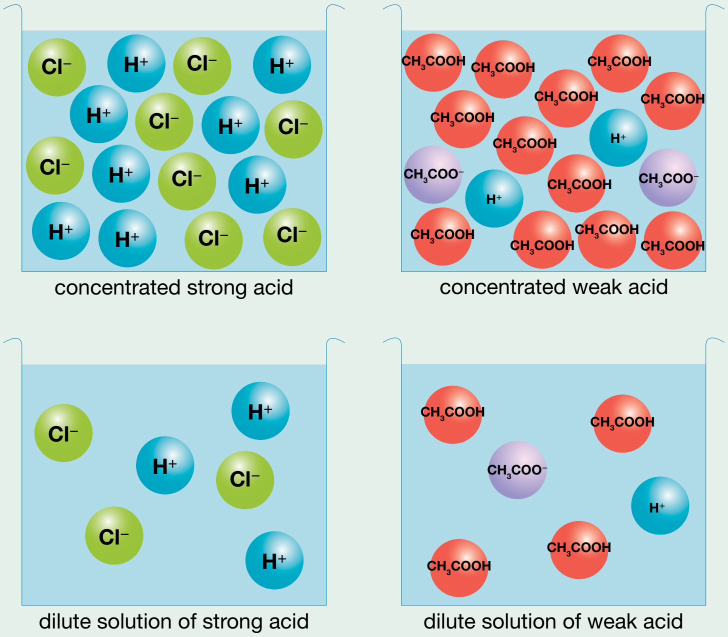
- A strong acid or base completely separates in water.
- A weak acid or base only partially separates in water.

The concentration of an acid or base is different to its strength. Concentration is how much of the actual active substance is in the solution; this determines the extent of reaction.

- A concentrated acid or base will have a large number of active particles in a given volume.
- A dilute acid or base will have a small number of active particles in a given volume.

The difference between strong/weak and concentrated/dilute is shown in figure 7.16.

FIGURE 7.16 Concentrated and dilute weak and strong acids



Neutralisation in the garden

Neutralisation reactions are used in many situations around the home. A sting from an ant or a bee is very painful as it contains an acid — formic acid. This can be neutralised by a base such as soap or a mixture of water and baking soda. A wasp sting is painful because it contains a base and can be treated by applying an acid such as vinegar. It is important to know what has bitten you so that the correct substance can be used to neutralise the sting.

Some plants grow better in acidic soils, while other plants grow best in basic soils. If a soil is too acidic, it can be neutralised with a base such as lime. The added lime can make the soil less acidic, neutral or basic, depending on how much is added.

If the soil is too basic, ammonium sulfate can be added to the soil. This reacts with the soil to produce an acid, which helps to neutralise the bases in the soil. These neutralisation reactions in your garden can help your plants to grow by providing soil with the most suitable pH.

TABLE 7.1 Common acids and bases and their uses

Acid	Uses
Hydrochloric acid (HCl)	• To clean the surface of iron during its manufacture • Food processing • The manufacture of other chemicals • Oil recovery
Nitric acid (HNO_3)	• The manufacture of fertilisers, dyes, drugs and explosives
Sulfuric acid (H_2SO_4)	• The manufacture of fertilisers, plastics, paints, drugs, detergents and paper • Petroleum refining and metallurgy
Citric acid ($C_6H_8O_7$)	• Present in citrus fruits such as oranges and lemons • Used in the food industry and the manufacture of some pharmaceuticals
Carbonic acid (H_2CO_3)	• Formed when carbon dioxide gas dissolves in water; present in fizzy drinks
Ethanoic acid (CH_3COOH)	• Found in vinegar • The production of other chemicals, including aspirin
Base	**Uses**
Sodium hydroxide ($NaOH$) (caustic soda)	• The manufacture of soap • As a cleaning agent
Ammonia (NH_3)	• The manufacture of fertilisers and in cleaning agents
Sodium bicarbonate ($NaHCO_3$)	• To make cakes rise when they cook

SCIENCE INQUIRY SKILLS: Spills in the laboratory

How are acid or base spills cleaned up in the science laboratory? Find out from your teacher or laboratory technician how spills are dealt with in your school.

It is important to deal with spills quickly and safely. The first thing to do is to let your teacher know if you have spilled any substance. Methods of dealing with spills may include acid or base neutralisers, absorption pads, mops or granules and inactivators. One thing you would not do is to try to neutralise a strong acid with a base as the reaction could be violent and cause further problems.

Indigestion

The hydrochloric acid in your stomach helps to break down the food you eat. It is a very strong acid, with a pH of less than 1.5. But if you eat too quickly, or eat too much of the wrong food, the contents of your stomach become even more acidic. You feel a burning sensation because of the corrosive properties of the acid, this is called indigestion.

To relieve the pain of indigestion, you can take antacid tablets. The active ingredients in antacid tablets are weak bases such as aluminium hydroxide, magnesium carbonate and magnesium hydroxide, which neutralise the acid. The cause of the relief you experience can be described by chemical equations such as:

$$\text{hydrochloric acid} + \text{aluminium hydroxide} \rightarrow \text{aluminium chloride} + \text{water}$$
$$3HCl + Al(OH)_3 \rightarrow AlCl_3 + 3H_2O$$

$$\text{hydrochloric acid} + \text{magnesium hydroxide} \rightarrow \text{magnesium chloride} + \text{water}$$
$$2HCl + Mg(OH)_2 \rightarrow MgCl_2 + 2H_2O$$

$$\text{hydrochloric acid} + \text{magnesium carbonate} \rightarrow \text{magnesium chloride} + \text{water} + \text{carbon dioxide}$$
$$2HCl + MgCO_3 \rightarrow MgCl_2 + H_2O + CO_2$$

One product of this last reaction is carbon dioxide gas. You burp to get the gas out of your stomach.

Acids and bases in the kitchen

Some foods, such as pickles, chutney and tomato sauce, last a long time without refrigeration because they contain acids that prevent the growth of micro-organisms that would cause them to spoil. Others, such as onions and beetroot, are preserved by storing them in vinegar, which is also known as ethanoic acid. This process of preserving food is called **pickling**.

The base sodium bicarbonate is more commonly known as baking soda. When it reacts with an acid, the products are a salt, water and carbon dioxide. Self-raising flour is a mixture of an acid and baking soda. When water or milk is added to self-raising flour, the acid and base react together. The carbon dioxide produced causes the mixture to rise when it is heated.

Two ingredients in pancakes are buttermilk (an acid) and baking soda. When the two are mixed, a salt, water and carbon dioxide are produced. The bubbles of carbon dioxide get larger as the mixture is heated, causing the mixture to rise.

ACTIVITY: Investigating food

Predict the outcomes of increasing the temperature of a pancake or damper mixture by adding a warm liquid to the dry ingredients. Try making pancakes yourself or research a recipe for damper to try at home. Most recipes use self-raising flour, milk or water, salt and butter.

Swim safely

When chlorine is added to a swimming pool, it reacts with the water to produce hypochlorous acid. This acid kills bacteria and algae, keeping the pool water safe for swimming. All the chemicals in a swimming pool, when combined, need to have a pH in the range of 7.2–7.8 for a clean, hygienic pool and safe swimming.

If the pH falls below 7.2, the micro-organisms will still be killed but the swimmers will get red and stinging eyes, and the water may become corrosive and damage pool fittings. A base such as sodium carbonate (soda ash) or sodium bicarbonate (bicarbonate of soda) would have to be added to neutralise the excess acid.

If the pH rises above 7.8, bacteria and algae will grow and the water will be unfit for swimming. To reduce the pH, an acid such as sodium hydrogen sulfate would have to be added to neutralise the excess base.

pickling preserving food by storing it in vinegar (ethanoic acid)

Protecting your teeth from corrosive acids

Acids are corrosive. They can dissolve metals, eat away marble statues, destroy the enamel of your teeth and kill bacteria.

Because acids are corrosive, they can be very harmful. Strong acids can burn your skin and eat away clothes. If an acid is spilt on the floor, a basic powder, such as sodium bicarbonate, should be used to neutralise the acid. All spills in the science lab should be reported to your teacher.

Acid can destroy the enamel on your teeth. Teeth are protected by a 2 mm thick layer of enamel made of hydroxyapatite. After a meal, bacteria in the mouth break down some of the food to produce acids such as acetic acid and lactic acid. Food with a high sugar content produces the most acid. The acids produced by the bacteria can dissolve the enamel coating of the tooth. Once this protective coating is destroyed, the bacteria can get inside the tooth and cause tooth decay. The best way to prevent this chemical reaction between tooth enamel and acid from happening is to clean and floss your teeth after every meal and avoid eating sugary foods.

on Resources

Video eLesson The effects of cola soft drinks on a tooth over a year (eles-2588)

CASE STUDY: Acid–base reactions in sherbert

The fizzy sensation that you get when you eat sherbet is due to an acid–base reaction. The sherbet consists of sodium bicarbonate and citric acid. Both of these substances are in powdered form in the sherbet and do not react with each other. When they dissolve in the saliva of your mouth a reaction takes place, producing carbon dioxide gas and hence the fizzing.

elog-0105

INVESTIGATION 7.4

Antacids in action

Aim

To investigate the neutralising action of an antacid

Materials

- Petri dish
- electronic balance
- spatula
- antacid powder
- 0.1 M hydrochloric acid
- 250 mL conical flask
- 100 mL measuring cylinder
- methyl orange indicator
- white tile or white paper

Method

1. Measure and record the mass of the Petri dish.
2. Add a small amount of antacid powder to the dish and record the mass of the antacid and Petri dish.
3. Add 50 mL of the dilute hydrochloric acid to the 250 mL flask.
4. Add 3 drops of methyl orange indicator.
5. Place the flask mixture on the white tile (or paper) and use the spatula to slowly add antacid from the Petri dish bit by bit. Swirl the flask to mix. Stop adding antacid when the colour changes from red to orange.
6. Measure and record the mass of the Petri dish and its contents (the unused antacid).

Results

1. What was the mass of the antacid powder?
2. What colour change occurs when the methyl orange indicator is in the acid?
3. By subtraction, calculate the mass of antacid used to neutralise 50 mL of dilute hydrochloric acid.

Discussion

1. How does your result agree with other groups in your class? Suggest reasons for the similarities or differences between your results.
2. Use your results to calculate how much antacid you would need to neutralise 500 mL of dilute hydrochloric acid.

Conclusion

Write a conclusion summarising your results. You may choose to discuss any variations in results across your class.

7.4.4 Acids and metals

When an acid reacts with a metal, the products are a salt and hydrogen gas.

The word equation for an acid–metal chemical reaction is:

acid + metal → salt + hydrogen

For example:

sulfuric acid + magnesium → magnesium sulfate + hydrogen

$$H_2SO_4 + Mg \rightarrow MgSO_4 + H_2$$

on Resources

Video eLesson Reaction between zinc powder and concentrated hydrochloric acid (eles-2589)

elog-0107

INVESTIGATION 7.5

Reaction of acids with metals

Aim

To investigate the chemical reactions of an acid with a range of metals

Materials

- safety glasses
- bench mat
- test tubes and test-tube rack
- pieces of metal such as copper, iron, zinc, magnesium, aluminium
- dropping bottle of 2 M hydrochloric acid solution
- rubber stopper
- matches

Method

When an acid reacts with a metal, a salt is formed and hydrogen gas is given off. You can test for hydrogen gas by holding a lighted match at the mouth of the test tube. If the gas is hydrogen, it will explode and make a 'pop' sound.

CAUTION

Do not push the stopper into the test tube firmly. Just hold it in the top of the test tube for a few seconds.

1. Place a small piece of one of the metals in a test tube.
2. Add the acid to the test tube to a depth of 1 cm.
3. Observe the chemical reaction.
4. Test for hydrogen gas by holding a rubber stopper over the end of the test tube for a few seconds and then placing a lighted match at the mouth of the test tube.
5. Repeat the test with other metals.

Results

Construct a table to record your observations.

Discussion

1. When zinc metal reacts with hydrochloric acid, zinc chloride and hydrogen gas are formed. Write a word equation for this reaction.
2. When the lighted match produces a 'pop', the hydrogen gas is reacting with the oxygen in the air to form water. You may have noticed the water form at the top of the test tube after you performed the match test. Write a word equation for this chemical reaction.
3. Extension:
   a. Write chemical equations for the reactions between hydrochloric acid and each of the metals you tested.
   b. Write a chemical equation for the the hydrogen gas 'pop' test.

Conclusion

Write a conclusion to your experiment describing your results with various metals.

on Resources

eWorkbook Acids and bases (ewbk-3036)

assess on Additional automatically marked question sets

7.4 Exercise

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Select your pathway

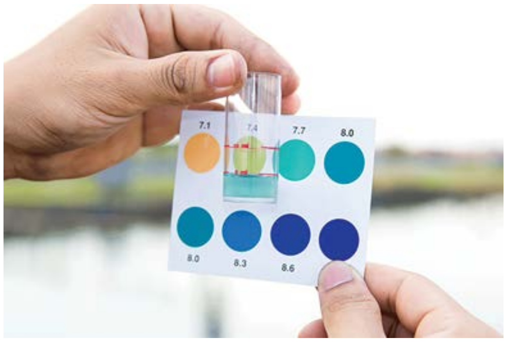
LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 6, 8, 9, 11, 12	Questions 4, 5, 7, 15, 16, 18	Questions 10, 13, 14, 17, 19, 20

Remember and understand

1. Complete the table by describing the properties of acids and bases.

	Acids	Bases
pH		
Taste		
Properties		

2. **MC** What common property do some acids and bases have when they come into contact with solid substances?
A. High pH
B. Low pH
C. They produce a gas
D. They are corrosive



3. **MC** Select the difference between a base and an alkali.
A. A base cannot be dissolved in an alkali.
B. A base can be dissolved in an alkali.
C. Bases that are dissolved in water are called alkalis.
D. Bases that cannot be dissolved in water are called alkalis.
4. Fill in the blanks to complete the following sentences.
a. The substance above has a pH value of ____________ and so it is ____________ .
b. A substance with a pH less than 7 is ____________.
c. A substance with a pH equal to 7 is ____________.
5. Explain why the chemical reaction between an acid and a base is called neutralisation.
6. **MC** Identify the substance that is produced in all neutralisation reactions?
A. Water
B. Smoke
C. An acid
D. A base
7. How does self-raising flour help cakes rise?
8. **MC** Which acid is present in your stomach to help you digest food?
A. Hydrochloric acid
B. Chloric acid
C. Citric acid
D. Sulfuric acid
9. **MC** Why does soap relieve the pain of an ant sting?
A. It cleans the bite area.
B. It neutralises the acidity of the venom.
C. It neutralises the base in the venom.
D. It creates an alkali.
10. Explain why foods high in sugar cause so much tooth decay.
11. **MC** A salt + ______ gas are formed in every chemical reaction between an acid and a metal.
A. oxygen
B. carbon dioxide
C. carbon monoxide
D. hydrogen
12. Write word equations for the reactions between:
a. Hydrochloric acid and sodium hydroxide

hydrochloric acid + ____________ → ____________ + water

b. Hydrochloric acid and sodium bicarbonate

hydrochloric acid + ____________ → sodium chloride + water + ____________

c. Sulfuric acid (hydrogen sulfate) and sodium hydroxide

sulfuric acid + ____________ → ____________ + water

Apply and analyse

13. SIS
    a. Describe how an antacid tablet relieve the pain of indigestion.
    b. Recall or re-read Investigation 7.2 in subtopic 7.2.3. Describe how you could change this investigation to model an acid stomach and antacid?
14. SIS A pH meter is used to measure the pH of 5 different substances. The results are as shown in the table.

TABLE pH of different substances

Substance	pH value
A	6.0
B	12.0
C	3.0
D	7.0
E	8.0

   a. Which substance is most likely to be:
      i. vinegar
      ii. milk?
   b. Which substance could be:
      i. a weak base
      ii. pure water
      iii. a strong base?
   c. Which two of the substances would you expect to be the most corrosive?
15. When you add buttermilk (an acid) to baking soda (a base) in a mixing bowl the pH increases. True or false? Explain your response.
16. Antacid tablets contain a base, which neutralises the excess acid coming from your stomach into your oesophagus and relieves the pain. When you take an antacid tablet, you would expect the pH value in your oesophagus to increase. True or false? Explain your response.

Evaluate and create

17. A stinging-nettle plant may contain an acid that is injected into your skin when you touch it. Construct a flow chart of four steps to describe how you could show that the plant does contain an acid using some of the following options.
    A. If the acid is neutralised
    B. Neutralise with a strong base
    C. The stinging feeling should be replaced by a slight burning sensation
    D. Such as a solution of bicarbonate of soda in water
    E. Such as sodium hydroxide
    F. Neutralise with an alkali.

18. Write a word equation to describe the chemical reaction between hydrochloric acid and calcium carbonate.
19. When a gardener adds lime to a soil that is too acidic, does that increase the pH? Explain.
20. SIS Find the websites of two antacid products such as Gaviscon®, Mylanta®, Eno® or Alka-Seltzer®.
    a. Research and report on:
       i the ingredients of the product or products
       ii the claims made about each antacid product or products
       iii advice and warnings
       iv side effects.
    b. Find a medical site that provides information about antacids, including side effects.

Fully worked solutions and sample responses are available in your digital formats.

7.5 Acid rain

LEARNING INTENTION

At the end of this subtopic you will be able to describe the effect of acid rain on the natural and built environment and how it can be reduced.

7.5.1 What causes acid rain?

Every year, **acid rain** causes hundreds of millions of dollars worth of damage to buildings and statues.

The photographs in figure 7.17 show the damage that has been caused to a statue over sixty years. Forests, crops and lakes are also affected by acid rain that is blown in from industrial areas.

Rain is normally slightly acidic. As clouds form and rain falls, the water reacts with carbon dioxide in the atmosphere to form very weak carbonic acid.

$$\text{water} + \text{carbon dioxide} \rightarrow \text{carbonic acid}$$
$$H_2O + CO_2 \rightarrow H_2CO_3$$

FIGURE 7.17 These photographs were taken in 1908 (left) and in 1969 (right). You can see the damaging effects of acid rain on this statue.

If concentrations of sulfur dioxide and nitrogen oxide are high in the atmosphere, these gases react with the water in the atmosphere to produce sulfurous acid, sulfuric acid, nitric acid and other acids.

$$\text{water} + \text{sulfur dioxide} \rightarrow \text{sulfurous acid}$$
$$H_2O + SO_2 \rightarrow H_2SO_3$$

$$\text{oxygen} + \text{sulfur dioxide} \rightarrow \text{sulfur trioxide} + \text{water} \rightarrow \text{sulfuric acid}$$
$$O_2 + SO_2 \rightarrow 2SO_3 + H_2O \rightarrow H_2SO_4$$

$$\text{water} + \text{nitrogen dioxide} \rightarrow \text{nitric acid} + \text{nitrogen monoxide}$$
$$H_2O + 3NO_2 \rightarrow HNO_3 + NO$$

When this rain falls, it is far more acidic than it would normally be and is known as acid rain. If the acid rain falls as snow, acid snow can build up on mountains. When this snow melts, huge amounts of acid are released in a short period.

acid rain rainwater, snow or fog that contains dissolved chemicals, such as sulfur dioxide, that make it acidic

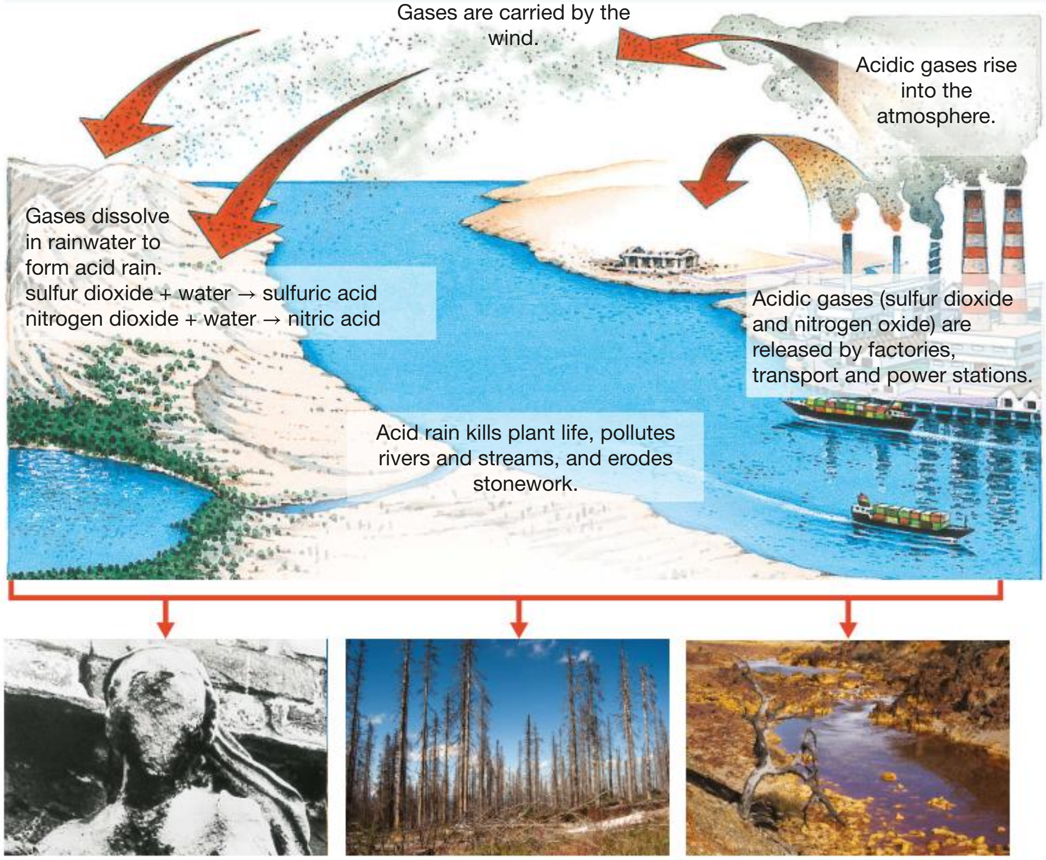
Where do the gases come from?

Most of the gases that cause acid rain come from the burning of fossil fuels (natural gas, oil and coal) in industry, power stations, the home and cars. Fossil fuels contain sulfur in varying amounts, and when sulfur is burned in air, it forms sulfur dioxide. Nitrogen dioxide also causes acid rain and it is produced by industry and every vehicle or machine driven by an internal combustion engine. North America, China, India and Europe have a greater problem with acid rain because of the use of coal with a higher sulfur content than Australian coal, and higher population densities. The sulfur dioxide released by volcanoes also contributes to acid rain.

7.5.2 Damage caused by acid rain

Acid rain damages the cells on the surface of leaves and affects the flow of water through plants. It also makes plants more likely to be damaged by frosts, fungi and diseases. The acid rain collects in streams, rivers and lakes, making the waterways more acidic. A healthy lake has a pH of about 6.5 and fish, plants and insects can live in it. Acid rain causes the pH of the lake to fall. Some aquatic plants and animals cannot tolerate these acidic conditions and die. It is not only the acidic water that can kill the aquatic life. Acid rain reacts with soil, releasing minerals, which may contain elements such as aluminium. The aluminium is washed into the streams, rivers and lakes and poisons the aquatic plants and animals.

Figure 7.18 The damage caused by acid rain



When acid rain eats into buildings and statues, it is reaching with calcium carbonate in the marble or limestone.
Calcium carbonate + acid rain → gypsum + water + carbon dioxide

Acid rain damages the cells on the surface of leaves and affects the flow of water through plants. It also makes plants more likely to be damaged by frosts, fungi and diseases. In northern Europe, entire forests have died as a result of acid rain.

Acid rain collects in streams, rivers and lakes, making the water more acidic. Acid rain causes the pH lakes to fall. Some aquatic plants and animals cannot tolerate these acidic conditions and die.

When acid rain eats into buildings and statues, it is reacting with calcium carbonate in the marble or limestone, as shown in this generalised reaction.

$$\begin{array}{ccccccccc} \text{calcium carbonate} & + & \text{acid rain} & \rightarrow & \text{gypsum} & + & \text{water} & + & \text{carbon dioxide} \\ CaCO_3 & + & H_2SO_4 & \rightarrow & CaSO_4 & + & H_2O & + & CO_2 \end{array}$$

You may recognise this as an acid–base reaction, with the base (calcium carbonate) reacting with acid to produce a salt (gypsum), water and carbon dioxide.

The gypsum formed by acid rain on a statue is a powdery dust (calcium sulfate), which is washed away by the rain. As this chemical reaction continues, the statue is slowly eaten away.

on Resources

Video eLessons Limestone reacting with hydrochloric acid (eles-2590)
Acid rain (eles-3525)

7.5.3 Solving the problem

The problem of acid rain and all the damage that it causes can be solved only by reducing the release of acidic gases into the air. Some ways of doing this include:

- looking for alternative ways of producing electricity
- encouraging people to use public transport, to car pool or change to electric vehicles
- setting air quality standards.

Since the US *Clean Air Act* was amended in 1990, sulfur dioxide emissions decreased by 88 per cent between 1990 and 2017 in the US. Nitrogen dioxide emissions are down 50 per cent over the same period.

The decrease in sulfur dioxide emissions in coal burning power stations is due largely to scrubbers that are fitted to the exhaust flues. These remove the hot gases and react them with chemicals, sometimes similar to limestone (calcium carbonate) to remove the sulfur dioxide. In recent years, the move towards renewable energy and away from coal-fired power stations has made significant improvements to the levels of acid rain in Australia.

elog-0109

INVESTIGATION 7.6

Investigating acid rain

Aim

To investigate the effect of pH of acidic water on the growth of seeds

Materials

- empty milk cartons
- potting soil
- distilled water
- measuring cylinder
- vinegar (or 0.1 M hydrochloric acid solution)
- seeds (for example, lucerne, peas, cress, beans)
- universal indicator

Method

1. Cut the milk cartons so that they are about 10 cm high. These will make suitable containers for growing the seeds, 5 seeds per container.
2. Design an experiment to test the effect of water with different pH values on the growth of the seeds. To ensure that your tests are fair, you will need to keep everything the same in your experiment, except the one thing that you are varying. In this case you are varying the level of acidity (pH) of the water that you are putting on the plants.

Discussion

Prepare a report on your investigation. This could be a written report, a video, a wall chart or an oral presentation.

on Resources

eWorkbook Acid rain (ewbk-3018)

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7.5 Exercise

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Select your pathway

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

Remember and understand

1. MC What gas is present in the air that makes rain slightly acidic even without air pollution?
   A. Carbon dioxide
   B. Nitrogen
   C. Oxygen
   D. Hydrochloric acid
2. Fill in the blanks to complete the following sentence.
   Acid rain is rain that has a ____________ than normal level of acidity. It occurs when ____________ and nitrogen oxides react with water in the atmosphere to form sulfuric, nitric and other acids. When rain forms it contains these acids, thus making acid rain.
3. Fill in the blanks to complete the following sentences.
   Acid rain harms plants by damaging the __________ on the surface of the leaves, interfering with water flow in the plant. This also makes plants more susceptible to __________. Acid rain can also make the acid level in streams very __________, and this can kill plants and animals that live in streams. As the acid rain runs off the soil it can also cause other substances, such as aluminium, to be released from __________. These substances can be __________ to plant and animal life in streams.

4. Complete this word equation:

$$\_\_\_\_\_\_\_\_\_\_ + \text{calcium carbonate} \rightarrow \text{gypsum} + \text{water} + \_\_\_\_\_\_\_\_\_\_$$

Apply and analyse

5. Motor vehicles make a large contribution to the acid rain problem. Most of them use fuel that releases acidic nitrogen oxides when it is burned. Write an account of some ways in which motor vehicle pollution could be reduced over the next thirty years.
6. SIS Design a wall chart that would explain how acid rain is formed and the damage that it can cause.

Evaluate and create

7. Find out some of the ways that damage caused by acid rain could be stopped or at least reduced.
8. Find out which countries are most affected by acid rain.

Fully worked solutions and sample responses are available in your digital formats.

7.6 Combustion reactions

LEARNING INTENTION

At the end of this subtopic you will be able to describe what combustion is and how it is used to provide energy as fuels for our bodies and machines we rely on.

7.6.1 Combustion reactions

Some of the most spectacular chemical reactions to watch, including fireworks and the launching of spacecraft, are **combustion** reactions.

Combustion reactions are those in which a substance reacts with oxygen and heat is released. Burning is a combustion reaction that produces a flame. The substance that reacts with oxygen in a combustion reaction is called a **fuel**.

7.6.2 Fossil fuels

Fossil fuels such as natural gas, petrol and coal have formed from the remains of living things. They are compounds of hydrogen and carbon called **hydrocarbons**. The products of the combustion of fossil fuels always include carbon dioxide and water. Because of impurities in fossil fuels, other products of their combustion include sulfur- and nitrogen-rich gases. In some cases various dangerous gases, including carbon monoxide, are also produced. Carbon dioxide, methane and nitrous oxide are the main greenhouse gases produced by human activities and make the largest contributions to the **enhanced greenhouse effect** and climate change.

combustion a chemical reaction when a substance reacts with oxygen and heat is released

fuel a substance that is burned in order to release energy, usually in the form of heat

fossil fuels substances, such as coal, oil and natural gas, that have formed from the remains of ancient organisms; they can be burned to produce heat

hydrocarbons compounds containing only hydrogen and carbon atoms

enhanced greenhouse effect the additional heating of the atmosphere due to the presence of increased amounts of carbon dioxide, methane and other gases produced by human activity

The combustion of hydrocarbons can be summarised as:

$$\text{hydrocarbon} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water} \ (+ \text{energy})$$

The word *combustion* comes from the Latin word *comburere*, meaning 'to burn'.

EXTENSION ACTIVITY: Incomplete combustion

If not enough oxygen is supplied to a combustion reaction, then incomplete combustion can occur. This creates different products apart from the carbon dioxide and water, including carbon monoxide and particles of carbon commonly called soot. Carbon monoxide is very dangerous as it is colourless, odourless and can cause you to become unconscious very quickly. This is why it is important to have a well-ventilated space when combustion is occurring, to allow oxygen in and to let carbon monoxide out.

A Bunsen burner can be used to show the results of incomplete combustion, if a heat mat or test tube is held over the flame. The least efficient flame can produce black soot. Predict which flame will produce incomplete combustion, the yellow flame or the blue flame? Test your prediction. Consider the combustion reaction for methane shown in the next section, and try to write a chemical equation showing the incomplete combustion of methane, which produced carbon monoxide (CO).

Cooking with gas

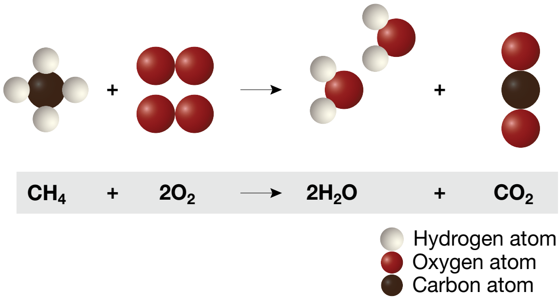
The **natural gas** used in gas stoves and ovens contains **methane**, a colourless, odourless and highly flammable gas. Natural gas formed millions of years ago from the remains of plants and animals and became trapped under rock. Its lack of colour and odour makes it very dangerous if there is a leak, so gas suppliers add chemicals that do have an odour so that the methane can be detected in the event of a leak or if the gas is accidentally left switched on. Methane reacts with oxygen, producing carbon dioxide and water, and it burns with a blue flame. The heat needed to start the reaction is provided by a match, lighter or spark.

FIGURE 7.19 Natural gas contains methane.

The equation for the combustion of methane is:

$$\text{methane} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water}$$
$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

FIGURE 7.20 Models showing the combustion of methane reaction



$$CH_4 + 2O_2 \longrightarrow 2H_2O + CO_2$$

Transport and electricity

The fuel used in most Australian cars is liquid **octane**. This is the major component of petrol, usually between 85 per cent and 95 per cent — other fuels make up the remainder. One of these fuels is ethanol, which is similar to octane but has less carbon atoms. The ethanol content of a fuel is sometimes displayed as E10, which means the fuel contains 10% ethanol. Octane is obtained from **crude oil** which, like natural gas, is formed from the remains of marine plants and animals that died million of years ago. The vapour of liquid octane reacts with oxygen, producing carbon dioxide and water. The reaction is started in each cylinder of a car by a spark from a spark plug. Most of the energy released during the reaction is used to turn the wheels of the car.

natural gas formed from the remains of plants and animals that died millions of years ago; it is a fossil fuel

methane the smallest hydrocarbon (CH_4), it is the main component of natural gas

octane a hydrocarbon with eight carbon atoms, it is the major component of petrol (C_8H_{18})

crude oil liquid formed from the remains of marine plants and animals that died millions of years ago—a fossil fuel. Many other fuel products are obtained from crude oil

EXTENSION: Why is ethanol added to fuel?

Ethanol belongs to the group of compounds known as alcohols. It has the chemical formula C_2H_5OH. It is an alcohol because it contains an oxygen atom and a hydrogen atom joined together in what is called a hydroxyl group (-OH). Ethanol is added to fuel as it reduces the pollution emitted and contributes fewer greenhouse gases. The presence of oxygen in the ethanol assists the complete combustion of the petrol, this reduces the emissions of poisonous carbon monoxide (CO) and other pollutants. Another environmental advantage of using ethanol, is that it can be produced from waste products of sugar production.

FIGURE 7.21 Ethanol is added to most unleaded fuel in Australia and is known as E10 fuel.

The equation for the combustion of octane is:

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

$$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$$

The fuel used in jet aircrafts is **kerosene**, which is obtained from crude oil. Kerosense is a mixture of hydrocarbons and so does not have a single chemical formula. It contains between 12 and 15 carbon atoms. Like the octane in cars, the vapour of this fossil fuel reacts with oxygen and combusts to produce carbon dioxide and water. An electrical spark is used to start the reaction.

In 2019, about 76 per cent of Australia's electricity was generated by the burning of fossil fuels, largely coal. The energy released during the combustion reaction is used to heat water to produce steam. The steam turns the blades of giant turbines, transforming its energy into electrical energy. Details of this process are discussed in Topic 10.

7.6.3 Essential combustion

A chemical reaction called **respiration** takes place in every cell of your body. Respiration is a slow combustion reaction. The energy required by your body is released when the fuel, glucose from your digested food, reacts with oxygen from the air that you breathe. The products of respiration are carbon dioxide and water. The energy produced is known as ATP.

kerosene fuel used in jet aircraft

respiration the process by which your body gains energy by breaking down glucose, using oxygen and creating carbon dioxide and water; a slow combustion reaction

The chemical equation for respiration is:

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

$$C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O + \text{ATP}$$

7.6.4 Blasting off

The energy to launch spacecraft is provided by a combustion reaction. The main rocket engines are fuelled by hydrogen, which reacts with oxygen in an exothermic reaction that releases enough energy to lift more than two million kilograms off the ground towards outer space. The only product of the reaction is water. Hydrogen fuel is a very clean energy source as it produces no carbon emissions. However, it is expensive to develop and hydrogen is difficult to transport safety. Technological developments for hydrogen as a fuel are occurring rapidly, with some countries using hydrogen fuel for their mass transport, such as buses.

The chemical equation for the combustion of hydrogen is:

$$\text{hydrogen} + \text{oxygen} \rightarrow \text{water}$$
$$2H_2 + O_2 \rightarrow 2H_2O$$

CASE STUDY: Hydrogen-fueled space travel

The US Space program has used hydrogen fuel cells for all of their missions to space.

The Space Shuttle would consume nearly 3 million litres of liquefied hydrogen gas on each mission. On the International Space Station, hydrogen is created by splitting water into oxygen for breathing and hydrogen for fuel. In the future, hydrogen will be further recycled by recombining it with exhaled carbon dioxide to create water. Hydrogen generation and recycling in space will reduce the need for supplies to be delivered from Earth and may bring us closer to a trip to Mars.

FIGURE 7.22 Cargo rocket delivering supplies to the ISS

7.6.5 Oxidation reactions

Combustion reactions are examples of **oxidation** reactions. However, strangely enough, not all oxidation reactions involve oxygen. Oxidation is now defined as the loss of electrons from a reactant. That is what happens to fuels when they are burned in oxygen. The reaction between copper and a silver nitrate solution is an example of an oxidation reaction that does not involve oxygen. Copper is oxidised when electrons are removed from copper atoms during the reaction that produces silver metal. This type of reaction is now known as an oxidation–reduction reaction, or for short, a redox reaction. The redox reactions you would be most familiar with are the reactions of fireworks exploding.

FIGURE 7.23 Fireworks are examples of explosive redox reactions.

oxidation a chemical reaction involving the loss of electrons by a substance

Resources

eWorkbook Combustion (ewbk-3020)

Video eLessons NASA Titan 3e Centaur launches with voyager probes from Cape Canaveral in the morning (eles-2592)
Time lapse view of fireworks near Flinders Street Station (eles-2591)

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7.6 Exercise

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Select your pathway

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

Remember and understand

1. Fill in the blanks to complete the sentence.
   What characteristics do all combustion reactions have in common?
   Fuel reacts with __________ producing ____________.
2. Fossil fuels are different from other types of fuel because they are formed from the remains of living things. True or false? Explain.
3. How is each of the following combustion reactions started?
   a. The burning of natural gas
   b. The combustion of octane in a car
4. MC Identify the products of all complete combustion reactions in which fossil fuels are burned.
   A. Carbon dioxide and oxygen
   B. Carbon dioxide and water
   C. Water vapour and oxygen
   D. Carbon and water

5. MC Which three of the substances below could be the product of an incomplete combustion reaction?
   A. Carbon
   B. Carbon dioxide
   C. Carbon monoxide
   D. Sulfur
   E. Sulfur dioxide
   F. Nitrogen
   G. Nitrogen dioxide
6. MC Identify the fuel in the combustion reaction known as respiration.
   A. Glucose
   B. Carbon dioxide
   C. Water
   D. Chlorophyll

Apply and analyse

7. Describe at least two effects on the environment of the combustion of fossil fuels.

8. MC Hydrogen and oxygen are cooled to extremely low temperatures so that they can be stored as liquids in the fuel tanks of rockets. Why is water, the product of the reaction, produced as a gas?
   A. The reaction between hydrogen and oxygen is highly exothermic.
   B. The reaction between hydrogen and oxygen is highly endothermic.
   C. So it can escape.
   D. So it can be captured and reused.
9. Respiration is the chemical reaction that takes place in every cell of your body. State two reasons it is classified as a combustion reaction.
10. Write an equation for an oxidation reaction that does not involve oxygen.
11. Find out how kerosene and octane are extracted from crude oil.

Evaluate and create

12. SIS Create a poster that shows how the burning of coal is used to generate electricity. Include the chemical equation for the combustion of coal on your poster. Also include information about where the reactants come from and what happens to the products.
13. SIS Different fuels produce different amounts of heat. The table shows the amount of heat produced per gram of fuel.

TABLE Heat of combustion for different fuels

Fuel	Heat of combustion (kJ per gram)
Hydrogen	141
Methane	55.6
Butane	49.7
Octane	47.9

   a. Write an equation for the combustion of butane.
   b. Create a bar graph of the information in the table.
   c. Which fuel produces the most heat per gram?

Fully worked solutions and sample responses are available in your digital formats.

7.7 Thinking tools — Matrixes and plus, minus interesting charts

7.7.1 Tell me

What is a matrix?

A matrix is a very useful thinking tool that can assist you to identify similarities and differences between topics. They are sometime called tables, grids or a decision chart.

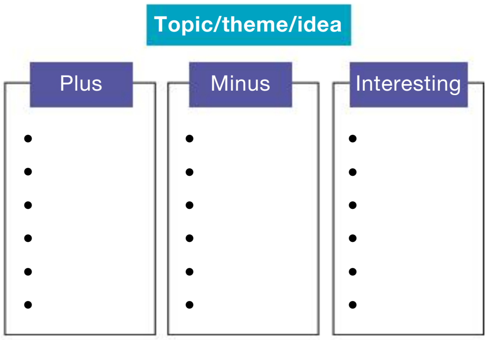
Why use a matrix instead of a PMI chart?

Similar to a matrix, a plus, minus, interesting chart (PMI) can be used to examine the key features of a topic and can help you to make a decision. However, PMI charts look at positive (plus), negative (minus) and interesting aspects of something. Matrixes can have a broader application.

FIGURE 7.24 A matrix

Topic	Feature A	Feature B	Feature C	Feature D	Feature E
1	✓		✓	✓	✓
2		✓			✓
3		✓		✓	✓
4			✓	✓	✓

FIGURE 7.25 A PMI chart



7.7.2 Show me

To create a matrix:

1. Write the topics in the left-hand column of the matrix.
2. Write the characteristics to be compared along the top row of the matrix.
3. If a characteristic applies to a topic, put a tick in the appropriate cell of the matrix.
4. The matrix now shows how the various topics are related.

Figure 7.26 shows a matrix comparing energy of various devices.

FIGURE 7.26 Matrix comparing energy of different devices

Object or device	Light energy	Thermal energy	Electical energy
Torch	✓	✓	✓
Portable stove	✓	✓	
Instant icepack		✓	

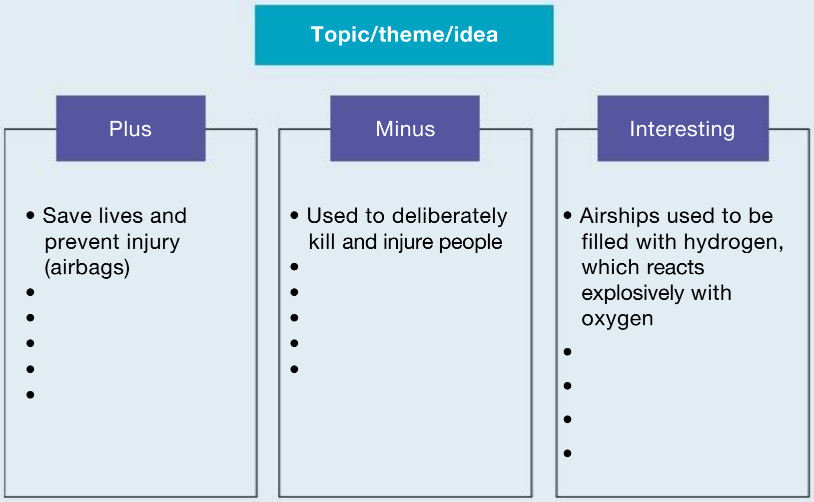
7.7.3 Let me do it

7.7 ACTIVITIES

1. Copy and complete the matrix below to show which type of chemical reaction refers to which statement.

Statement	Endothermic reactions	Exothermic reactions	Neutralisation reactions	Combustion reactions
Chemical bonds are always broken.				
New chemical bonds are formed.				
Energy is released to the surroundings.				
Energy is absorbed from the surroundings.				
The Law of Conservation of Mass applies.				
A salt is always produced.				
Oxygen is always a reactant.				
One reactant is always an acid.				
Respiration in living cells is an example.				
Takes place to inflate a car airbag.				
A new substance is produced.				

2. Create your own PMI chart on chemical explosions, using the diagram below as a starting point.



3. Create your own PMI on the use of fossil fuels.

Fully worked solutions and sample responses are available in your digital formats.

7.8 Project — *ChemQuiz*

Scenario

Australians young and old love a good quiz show. Whether it's *Hard Quiz* or *The Chase* programs with a quiz show format rate consistently well. While the idea of watching someone answer questions seems like an odd form of entertainment, psychologists theorise that their popularity arises from a combination of a desire to learn new information and a form of competition — after all, who hasn't watched a quiz show and yelled the answers at the screen? In recent educational studies, the use of quiz game formats as a teaching tool in the classroom is gaining support.

The Brain Mine is a company that specialises in educational resources for use in Science classrooms. On the basis of these educational studies of quiz games, they have decided that they would like to add a computer-based chemistry quiz show that teachers could purchase and run in their classrooms as a fun and effective way of improving student knowledge. As product developers at The Brain Mine, it is up to you and your team to make this happen! You and your team are going to develop *ChemQuiz*, a chemistry-based quiz show in which the class teacher will act as the show host, groups of students will be the contestants and the questions (which pop up on a computer screen so that the contestants can see them) are based on chemistry skills.

Your task

Using PowerPoint, you will create a series of question screens for a quiz show that should run for about ten minutes. For each question screen, the show host must be able to reveal the correct response after a contestant has given their answer. The question screens should be entertaining and eye-catching, and should also be easily readable by the contestants and the show host (who will read the questions out as they appear.

You will need to give a demonstration of your *ChemQuiz* show with one of your group acting as the show host (the role that would normally be taken by the teacher). The show host will need to explain the rules of the quiz show at the start. The contestants will be your fellow students (preferably not those in your group, who will already know the answers!).

Resources

ProjectsPLUS *ChemQuiz* (pro-0107)

7.9 Review

Access your topic review eWorkbooks

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-3022	ewbk-3024	ewbk-3026

on Resources

7.9.1 Summary

Rearranging atoms and molecules

- Chemical reactions take place when the bonds between atoms are broken and new bonds are formed creating a new arrangement of atoms and at least one new substance.
- Reactants in chemical reactions are written on the left-hand side of an equation and products are written on the right.
- The Law of Conservation of Mass states that matter can neither be created nor destroyed.
- The Law of Constant Proportions states that a compound, no matter how it is formed, always contains the same relative amounts of each element.

Chemical reactions and energy

- Many chemical reactions must be initiated by an input of energy.
- Endothermic reactions absorb heat and exothermic reactions release heat.
- Endothermic processes absorb heat from the surroundings, but the chemical reaction involved in the process can be reversed.
- Airbags are powered by a reaction that produces a large amount of gas in a very short time.
- Alfred Nobel invented a stable version of dynamite.

Acids and bases

- Acids are corrosive substances and have a pH below 7, which is neutral.
- Bases are corrosive substances and have a pH above 7. Bases that can be dissolved in water are called alkalis.
- The pH scale ranges from 0 to 14.
- Acid–base indicators are substances that can be used to tell whether a substance is an acid or a base.
- A neutralisation reaction occurs when an acid and a base react with each other, the products include water and a salt.
- Indigestion is an excess of hydrochloric acid in the stomach, which can be neutralised by an antacid.
- When an acid reacts with a metal, the products are a salt and hydrogen gas.

Acid rain

- Excessive sulfur dioxide and nitrogen oxide from industry react with the water in the atmosphere to produce sulfuric, nitric and other acids, which fall to the ground as acid rain.

Combustion reactions

- Combustion reactions occur when a fuel burns in oxygen gas to produce heat, water vapour and carbon dioxide.
- Incomplete combustion reactions occur when not enough oxygen is involved with the reaction.
- Fossil fuels such as octane are obtained from crude oil.
- Respiration is a type of combustion reaction involving glucose and oxygen to produce carbon dioxide and water.
- Rocket fuels include hydrogen, which burns in oxygen to produce water vapour.
- Combustion reactions are examples of oxidation reactions that involve the exchange of electrons.

7.9.2 Key terms

acid rain rainwater, snow or fog that contains dissolved chemicals, such as sulfur dioxide, that make it acidic
acids chemicals that react with a base to produce a salt and water; edible acids taste sour
alkalis bases that dissolve in water
bases chemical substances that will react with an acid to produce a salt and water; edible bases taste bitter
chemical energy energy stored in chemical bonds that is released during chemical reactions
chemical process changes the arrangement of the atoms or molecules of the substances involved
combustion a chemical reaction when a substance reacts with oxygen and heat is released
corrosive a chemical that wears away the surface of substances, especially metals
crude oil liquid formed from the remains of marine plants and animals that died millions of years ago—a fossil fuel. Many other fuel products are obtained from crude oil
dynamite relatively stable explosive invented by Alfred Nobel in 1866. It is created by mixing nitroglycerine with an absorbent substance such as silica, forming a paste that can be shaped into rods.
endothermic chemical reactions that absorb heat energy from the surroundings
enhanced greenhouse effect the additional heating of the atmosphere due to the presence of increased amounts of carbon dioxide, methane and other gases produced by human activity
exothermic chemical reactions that give out heat energy to the surroundings
fossil fuels substances, such as coal, oil and natural gas, that have formed from the remains of ancient organisms; they can be burned to produce heat
fuel a substance that is burned in order to release energy, usually in the form of heat
hydrocarbons compounds containing only hydrogen and carbon atoms
indicator a substance that changes colour when it reacts with acids or bases; the colour shows how acidic or basic a substance is
kerosene fuel used in jet aircraft
Law of Conservation of Mass in a chemical reaction, the total mass of the reactants is the same as the total mass of the products
Law of Constant Proportions in chemical compounds, the ratio of the elements is always the same
methane the smallest hydrocarbon (CH_4), it is the main component of natural gas
natural gas formed from the remains of plants and animals that died millions of years ago; it is a fossil fuel
neutralisation a reaction between an acid and a base. A salt and water (a neutral liquid) are the products of this type of reaction
octane a hydrocarbon with eight carbon atoms, it is the major component of petrol (C_8H_{18})
oxidation a chemical reaction involving the loss of electrons by a substance
pH scale the scale from 1 (acidic) to 14 (basic) that measures how acidic or basic a substance is
pickling preserving food by storing it in vinegar (ethanoic acid)
products chemical substances that result from a chemical reaction
reactants the original substances present in a chemical reaction
respiration the process by which your body gains energy by breaking down glucose, using oxygen and creating carbon dioxide and water; a slow combustion reaction
universal indicator a mixture of indicators that changes colour as the strength of an acid or base changes, indicating the pH of the substance

on Resources

eWorkbooks	Study checklist (ewbk-3028) Literacy builder (ewbk-3030) Crossword (ewbk-3032) Word search (ewbk-3034)
Practical investigation eLogbook	Topic 7 Practical investigation eLogbook (elog-0097)
Digital document	Key terms glossary (doc-34713)

7.9 Exercise

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 4, 9, 10, 11	Questions 3, 5, 8, 12, 14	Questions 6, 7, 13, 15, 16

Remember and understand

1. A particular chemical reaction can be described by the word equation:

   hydrochloric acid + magnesium carbonate → magnesium chloride + water + carbon dioxide

   a. MC Select the two reactants in this chemical reaction.
   A. Hydrochloric acid
   B. Magnesium chloride
   C. Water
   D. Magnesium carbonate
   E. Carbon dioxide

   b. MC Select all the products of the reaction.
   A. Hydrochloric acid
   B. Magnesium chloride
   C. Water
   D. Magnesium carbonate
   E. Carbon dioxide

   c. MC Identify from which compound did the atoms present in the carbon dioxide come?
   A. Hydrochloric acid
   B. Magnesium chloride
   C. Water
   D. Magnesium carbonate
   E. Carbon dioxide

   d. This is an exothermic reaction, so the reactants have more energy stored in their chemical bonds than the products. True or false? Explain.

2. MC What observable evidence demonstrates that a chemical reaction has taken place?
   A. The apparent disappearance of a substance
   B. The appearance of a new substance
   C. A release of energy (often heating the surroundings noticeably)
   D. Absorption of energy (cooling the surroundings)
   E. All of the above

3. Use the Law of Conservation of Mass to explain why it is incorrect to say that when a candle burns it disappears.

4. Fill in the blank to complete the sentence.
   The Law of Constant Proportions states that a compound always contains ____________ relative amounts of each element.

5. When hydrogen reacts with oxygen in a rocket engine, a huge amount of energy is released.

$$\text{hydrogen} + \text{oxygen} \xrightarrow{\text{heat}} \text{water}$$

   a. MC Why does the word ‘heat’ appear above the arrow in the chemical word equation? Select all relevant statements to explain your answer.
   A. Heat energy is required to initiate the reaction.
   B. Energy is required to break reactant bonds to create new bonds.

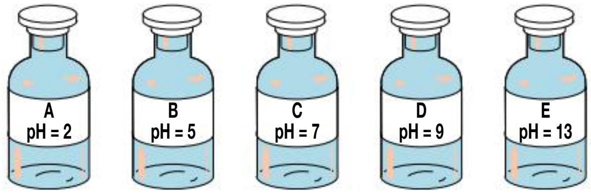
C. Energy is released when breaking reactant bonds to create new bonds.
D. Energy is a reactant, so must be shown above the arrow.
E. Energy is not a reactant, so must be shown above the arrow.

b. This reaction is endothermic. True or false? Explain.

6. Are the chemical reactions that convert the chemical energy stored in your muscles into other forms of energy endothermic or exothermic? How do you know?

Apply and analyse

7. The liquids in the bottles below are labelled with their pH. Which of the bottles is most likely to contain:



a. distilled water
b. a strong acid
c. black coffee
d. bathroom surface cleaner?

8. Predict the salts that would result from the neutralisation reaction between:
a. Magnesium oxide and hydrochloric acid
b. Copper (II) oxide and sulfuric acid
c. Sodium hydroxide and acetic acid
d. Sodium oxide and nitric acid

9. MC If the water in a swimming pool has a pH that is too high for hygienic and safe swimming, which type of pool chemical should be added?
A. An acid
B. A base
C. Water
D. Carbon dioxide

10. MC What acid or base is most commonly used in pickling?
A. Ethanoic (acetic) acid
B. Hydrochloric acid
C. Caustic soda
D. Fizzy drinks

11. Complete the following chemical word equation:

acid + metal → ____________ + hydrogen

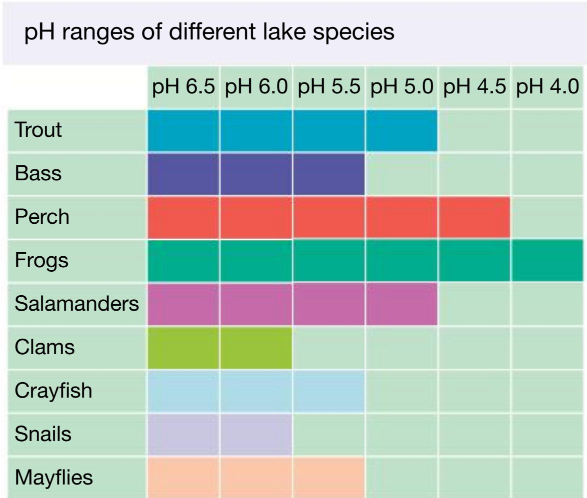
12. There are at least two reactants in every combustion reaction. One of them is called a fuel.
a. With what substance does the fuel react?
b. Identify one product of every combustion reaction.
c. One product of combustion reactions is not a chemical. What is it?

13. MC Identify two chemical products of combustion reactions in which fossil fuels are burned.
A. Carbon dioxide and hydrogen
B. Carbon dioxide and water
C. Water and hydrogen
D. Hydrogen and energy

14. Identify the main reactant in each of the following fuels in combustion reactions.
 a. Natural gas
 b. Petrol
 c. Jet aircraft fuel

Evaluate and create

15. One combustion reaction takes place in every cell of your body.
 a. State the name of this combustion reaction.
 b. Identify the reactants in the reaction.
 c. Identify two chemical products of the reaction.
 d. Write the chemical equation for this reaction.
16. SIS The diagram shows the organisms that are normally found in a particular lake and the pH of water that they are able to tolerate.



 a. Which of these species would start to die first if the lake water started to increase in acidity? Select all possible species.
 b. Which of the species is the most tolerant of high acid levels in the lake? Select all possible species.
 c. Which species would remain if the acidity of the lake water increased until it had a pH of 5.0? Select all possible species.

Fully worked solutions and sample responses are available in your digital formats.

on Resources

eWorkbook Reflection (ewbk-3038)

teachon

Test maker
Create customised assessments from our extensive range of questions, including teacher-quarantined questions.
Access the assignments section in learnON to begin creating and assigning assessments to students.

RESOURCE SUMMARY

on Resources

Below is a full list of **rich resources** available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

7.1 Overview

eWorkbooks
- Topic 7 eWorkbook (ewbk-3012)
- Student learning matrix (ewbk-3097)
- Starter activity (ewbk-3014)

Practical investigation eLogbooks
- Topic 7 Practical investigation eLogbook (elog-0097)
- Investigation 7.1: Cleaning up with baking soda and vinegar (elog-0099)

Video eLesson
- A strong acid is poured into a solution containing glucose (eles-2584)

7.2 Rearranging atoms and molecules

Practical investigation eLogbook
- Investigation 7.2: Conserving mass (elog-0101)

Video eLesson
- Priestley and the Law of Conservation of Mass (eles-1767)

7.3 Chemical reactions and energy

eWorkbook
- Exothermic and endothermic reactions (ewbk-3016)

Practical investigation eLogbook
- Investigation 7.3: Exothermic and endothermic processes (elog-0103)

Video eLesson
- An explosion in a quarry (eles-2587)

7.4 Acids and bases

eWorkbook
- Acids and bases (ewbk-3036)

Practical investigation eLogbooks
- Investigation 7.4: Antacids in action (elog-0105)
- Investigation 7.5: Reactions of acids with metals (elog-0107)

Video eLessons
- Universal indicator solution (eles-2304)
- The effects of cola soft drinks on a tooth over a year (eles-2588)

Interactivity
- The pH rainbow (int-0101)

7.5 Acid rain

eWorkbooks
- Acid rain (ewbk-3018)
- Limestone reacting with hydrochloric acid (eles-2590)

Practical investigation eLogbook
- Investigation 7.6: Investigating acid rain (elog-0109)

Video eLessons
- Acid rain (eles-3525)
- Limestone reacting with hydrochloric acid (eles-2590)

7.6 Combustion reactions

eWorkbook
- Combustion (ewbk-3020)

Video eLessons
- NASA Titan 3e Centaur launches with voyager probes from Cape Canaveral in the morning (eles-2592)
- Time lapse view of fireworks near Flinders Street Station (eles-2591)

7.8 Project — *ChemQuiz*

ProjectsPLUS
- *ChemQuiz* (pro-0107)

7.9 Review

eWorkbooks
- Topic review Level 1 (ewbk-3022)
- Topic review Level 2 (ewbk-3024)
- Topic review Level 3 (ewbk-3026)
- Study checklist (ewbk-3028)
- Literacy builder (ewbk-3030)
- Crossword (ewbk-3032)
- Word search (ewbk-3034)
- Reflection (ewbk-3038)

Practical investigation eLogbook
- Topic 7 Practical investigation eLogbook (elog-0097)

Digital document
- Key terms glossary (doc-34713)

To access these online resources, log on to **www.jacplus.com.au**.

8 The dynamic Earth

LEARNING SEQUENCE

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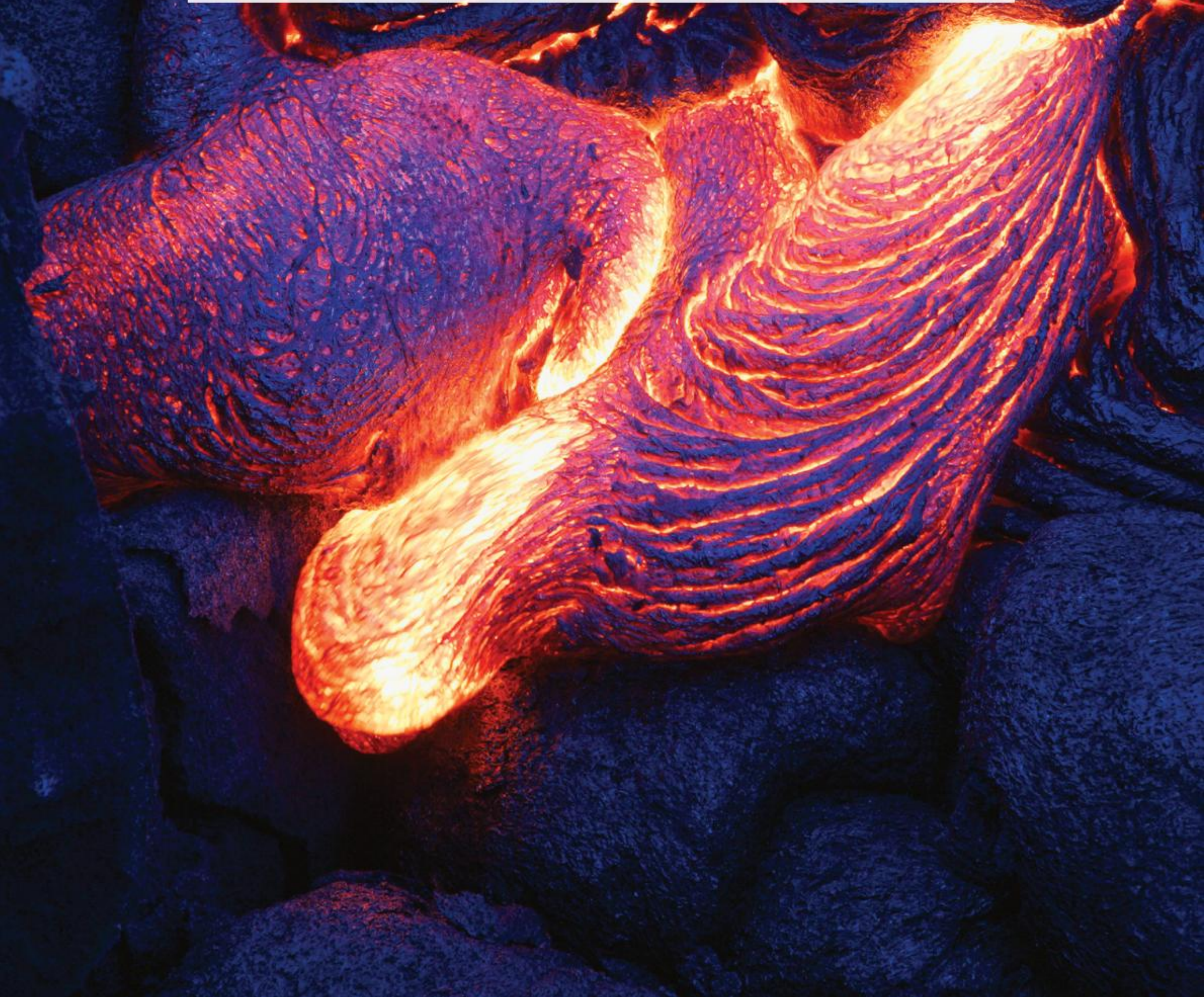
8.2 The Earth's crust 470
8.3 The theory of plate tectonics 476
8.4 Rocks under pressure 486
8.5 Earthquakes 492
8.6 Volcanoes 501
8.7 Thinking tools — Double bubble maps 507
8.8 Project — Disaster-proof 509
8.9 Review 510



8.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

8.1.1 Introduction

The ground beneath you seems still. It might even seem dull. But first appearances can be deceiving. In fact, the Earth's crust is not still — it is constantly moving and changing as seen by earthquakes. Nor is it dull — there are locations where red-hot molten rock is created, which sometimes bursts through and creates a volcano like the one shown in figure 8.1 (Eyjafjallajökull, Iceland, which erupted in 2010).

FIGURE 8.1 Molten lava erupts from Eyjafjallajökull, Iceland, 2010

Volcanoes and earthquakes provide spectacular evidence that the Earth is a dynamic, ever-changing planet. This activity can be both amazing and scary at the same time. However, there is a pattern to this activity, as the location of most volcanoes and earthquakes are controlled by the movements of Earth's tectonic plates. Tectonic plates are pieces of the Earth's crust that shift and move around relative to each other; more than 80 per cent of all volcanoes and earthquakes are formed along the boundaries of the tectonic plates. Take Iceland as an example. Here, two tectonic plates are moving away from each other forming large fissures in the crust, which allows hot material to rise up from the middle, melt and erupt to form inspiring volcanoes.

on Resources

Video eLesson Volcanic eruption in Iceland 2010, Eyjafjallajökull (eles-2661)

This short video of the eruption of Eyjafjallajökull was taken less than a kilometre from the crater. A lava flow, creating new rocks, can be seen in the bottom right of the screen.

8.1.2 Think about our dynamic Earth

1. How can something as large as a continent move?
2. Why do volcanoes make a 'ring of fire' around the Pacific Ocean?
3. How could someone have walked to Australia 250 million years ago?
4. Why do the Himalayas have many of the highest mountains on Earth?
5. What causes tsunamis?
6. How can a volcano suddenly appear from nowhere?
7. Where is the largest volcano in the solar system?

8.1.3 Science inquiry

Journey to the centre of the Earth

'Descend into the crater of Yokul of Sneffels, which the shade of Scataris caresses before the Kalends of July, audacious traveller, and you will reach the centre of the Earth. I did it.'

So wrote Jules Verne in his science fiction novel *Journey to the centre of the Earth*, which was published in 1864. The novel describes a fascinating journey by the adventurous Professor Lidenbrock, his nephew Axel and their guide Hans to the centre of the Earth. Their quest begins with a descent into the crater of the extinct volcano Snæfellsjökull in Iceland.

Although no one has ever been able to drill a hole, much less visit, the centre of the Earth in reality, geologists have made some scientific discoveries about what is deep inside the Earth. For starters, they found that the Earth is layered. The surface layer is called the **crust**, followed by the **mantle** and then the **core** at the very centre. As you move towards the centre, each layer is made of denser material — the heavy material sank to the bottom, while the lighter material stayed on top.

crust hard and thin outer rock layer of the Earth

mantle solid but soft middle rock layer of the Earth

core hot centre of the Earth made of iron and nickel

Think about the crust

When you look at an image of the Earth's surface the largest features are continents and ocean basins.

1. Are there any patterns to the size or locations of the continents and oceans?
2. Geologists consider the bulk of continental crust to be made of different rocks types compared to the oceanic crust.
   a. How might the wide range of crustal thickness in the data above be related to this?
   b. Which do you think is thinner, oceanic or continental crust?
3. Consider the material found close to the surface of the Earth — close enough to be able to reach with drills and tunnels. Make a list of material that are:
   a. used to provide energy for heating, transport and industry
   b. used for building and other construction
   c. exceptionally valuable.

Think about the mantle and core

As we travel towards the centre of the Earth, the weight of the rock above gets heavier, thus pressure ever increases as we make the journey. Temperature also increases, because rocks can contain radioactive material that decays and releases heat, keeping the interior of the Earth nice and toasty.

4. What do you imagine the state of the mantle to be like?
5. Jules Verne described Earth's interior to be full of interconnected caverns, a bit like swiss cheese. How valid is his description?
6. What would you expect to find at the very centre of the Earth?
7. The Earth's surface is constantly experiencing change. Make a list of events that cause change to the surface and evaluate which ones may be the result of a dynamic interior.
8. Scientists have estimated Earth to be approximately a sphere with an average radius of 6370 kilometres. Create a scaled-down model for the interior of the Earth to illustrate the three layers.

TABLE 8.1 Depth to each layer of the Earth

Earth layer	Average depth to top of layer	Average depth to bottom of layer
Crust	0 km	6–30 km
Mantle	6–30 km	2900 km
Core	2900 km	6370 km

on Resources

eWorkbooks	Topic 8 eWorkbook (ewbk-4473) Student learning matrix (ewbk-4472) Starter activity (ewbk-4475)
Practical investigation eLogbook	Topic 8 Practical investigation eLogbook(elog-0442)
learnon	Access and answer an online Pre-test and receive **immediate corrective feedback** and **fully worked solutions** for all questions.

8.2 The Earth's crust

LEARNING INTENTION

At the end of this subtopic you will be able to describe the Earth's distinct internal layers (crust, mantle, outer core, and inner core), and the theory of continental drift that was proposed to explain the movement of continents, including the supercontinent Pangaea.

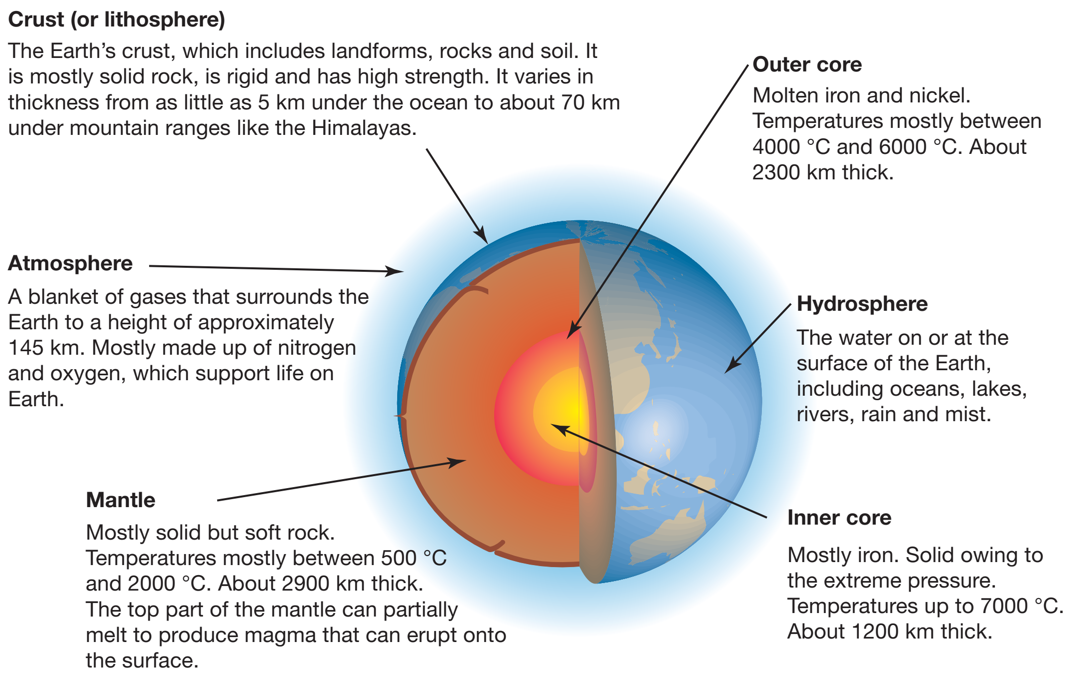
8.2.1 Structure of the Earth

The interior of the Earth has three basic layers: crust, mantle and core. The crust is the very thin, hard, outer layer of our planet. To get an idea of how thin the Earth's crust is, compare it to a medium-sized apple. Imagine that the apple is the Earth. The crust would be as thin as the skin of the apple. Two questions have intrigued geologists for more than a hundred years:

1. What lies beneath the crust?
2. Is everything stationary?

ewbk-4477
eles-4148
int-8163

FIGURE 8.2 Layers of the Earth



Questions about what is beneath the Earth's surface have inspired curiosity and imaginative writing — such as Jules Verne's novels. The idea of drilling through to or even travelling to the centre of the Earth is appealing. There could be no better way to find out what is down there. But the deepest man-made holes in the Earth have been drilled to only around 12 km of the 6370 km distance to the centre. So, how do geologists know that a mantle and core exist, and how do they investigate what they are like? Some methods include:

- the study of meteorites from space
- laboratory studies to determine temperature and pressure stability conditions for minerals and rocks
- measuring and interpreting seismic wave signals that have travelled through the Earth
- looking at features of the crust, which can provide clues to what happens beneath.

SCIENCE AS A HUMAN ENDEAVOUR: Imaging the interior of the Earth

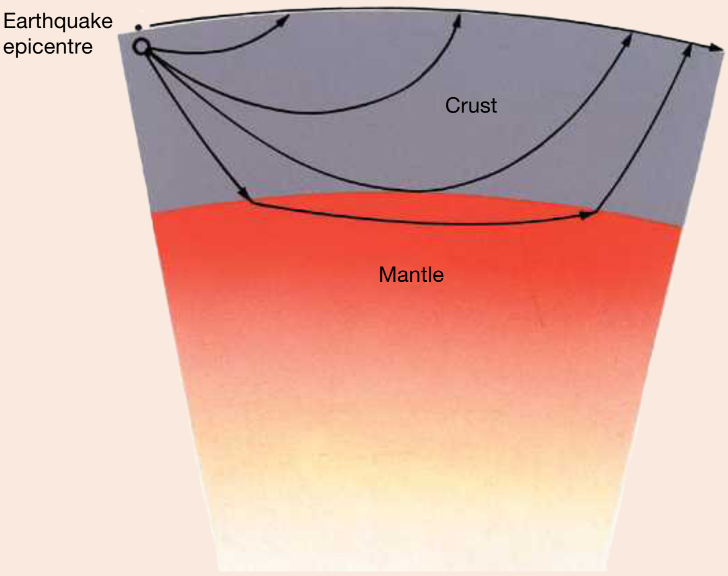
Geophysicists use data from earthquakes to find out what lies inside the Earth. Earthquakes produce **seismic waves** that transfer energy from the site of the earthquake (the epicentre) through the crust. It is the energy of these waves that causes destruction at the surface.

Seismic waves travel differently (speed and behaviour) as they pass through different substances below the crust. By analysing seismic waves, scientists have been able to identify the state and chemical composition of the substances inside the Earth. For example, the Earth's core is likely made of iron and nickel, but is divided into two layers, a liquid **outer core** and a solid **inner core**. Flow of the liquid outer core plays an important role for life on Earth, as it generates the Earth's magnetic field, which protects the surface from some of the most harmful solar radiation.

Consider the following questions.

- What else is the magnetic field useful for?
- Is the outer core the only Earth layer that moves?

FIGURE 8.3 Seismic waves travel through the Earth and return to the surface. When they interact with a new medium, like at the base of the crust (grey) the speed and travel path of the waves is altered.



seismic waves waves released when rock breaks or is rapidly moved

outer core liquid outer layer of the core, about 2300 km thick

inner core solid inner-most layer of the core under extreme pressure conditions, with an approximate 1200 km radius

8.2.2 The crust

There are two kinds of crust: continental and oceanic.

- The continents are made of continental crust, which you will recognise as the land.
- The ocean basins are made of oceanic crust, but in a few locations on Earth, slices of the oceanic crust have been observed on land. These unusual rocks are called ophiolites. Macquarie Island is an exposed ophiolite in the Pacific Ocean, halfway between New Zealand and Antarctica. It is a part of Tasmania and an UNESCO World Heritage Site.

Their shapes, nature and features can help clue geologists into what may be happening beneath.

TABLE 8.2 Thickness and density of continental crust and oceanic crust

Continental crust	Oceanic crust
Ranges from 25 to 70 kilometres thick	Ranges from 4 to 10 kilometres thick
Average density is 2.7 g/cm^3, similar to the rock granite	Average density is 3.0 g/cm^3, similar to the rock basalt

DISCUSSION

Where do you think the thickest continental crust would be? How could a geologist test your hypothesis?

8.2.3 Moving continents

Geologists of the 1800s believed that the Earth started off as a hot molten ball of rock material. As it cooled, a crust formed, and the Earth began to shrink. The shrinking size would cause the solid crust to wrinkle, in the same way that the skin of an apple wrinkles when it begins to rot. Geologists hypothesised that the continents, particularly mountain ranges, were the high parts of the 'wrinkles' and that oceans covered the lower parts. Accordingly, mountains would appear randomly all over the Earth's surface and constantly grow; volcanoes and earthquakes would also occur randomly.

As with all scientific theories, they can be challenged and evolve when new information is gathered. During the late 1800s and early 1900s, evidence was found that showed that the continents were moving.

The continental drift theory

In 1912, a German meteorologist and polar explorer named Alfred Wegener proposed a new theory. He suggested that the Earth isn't shrinking, but that continents were slowly drifting across the Earth over a weaker mantle, sometimes pushing through ocean crust and colliding with another continent. This process became known as **continental drift**.

Wegener also proposed that, at one time, all the continents were joined like pieces of a giant jigsaw puzzle into a single 'supercontinent' that he called **Pangaea**. Pangaea was surrounded by a vast ocean called **Panthalassa** and a smaller inlying ocean called Tethys. By about two hundred million years ago, Pangaea began to break into separate continents that have slowly drifted apart to their present positions.

continental drift movement of the Earth's continents relative to each other over geologic time

Pangaea a supercontinent that existed about 225 million years ago. All landmasses were joined together to form this supercontinent.

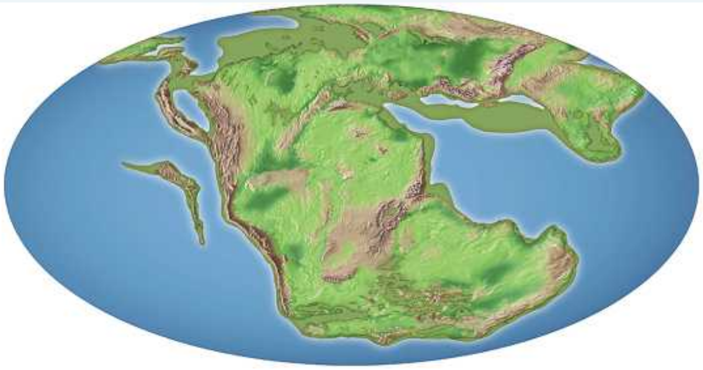
Panthalassa the vast ocean surrounding the supercontinent of Pangaea

fossils the remains, impression or trace of a living organism preserved in rock

Wegener's claims were based on several lines of evidence, including:

1. the present-day continents looked as though they would fit together, very much like a jigsaw puzzle
2. the discovery of **fossils** of the same land plants and animals on different continents now separated by large oceans
3. the distribution of unique rock deposits and features of the same age across continents
4. the discovery of plant fossils that clearly grew in a different climate than the current one.

FIGURE 8.4 The supercontinent of Pangaea as it would have appeared 200 million years ago, surrounded by Panthalassa Ocean



DISCUSSION

In what ways did continental drift affect the evolution of animals and plants living on Earth at the time?

on Resources

Video eLesson Drifting continents (eles-0129)

elog-0432

INVESTIGATION 8.1

Continental drift

Aim

To create a simple model to demonstrate continental drift

Materials

- enlarged copy of the map
- scissors

Method

1. Cut out the continents from the enlarged copy of the map provided.
2. Examine the distribution of fossils on each continent.
3. Rearrange the continents into one supercontinent by matching the distribution of fossils. For example, you want the pink trend of the Glossopteris (fern) fossil on one continent to align with another trend on a different continent.

Results

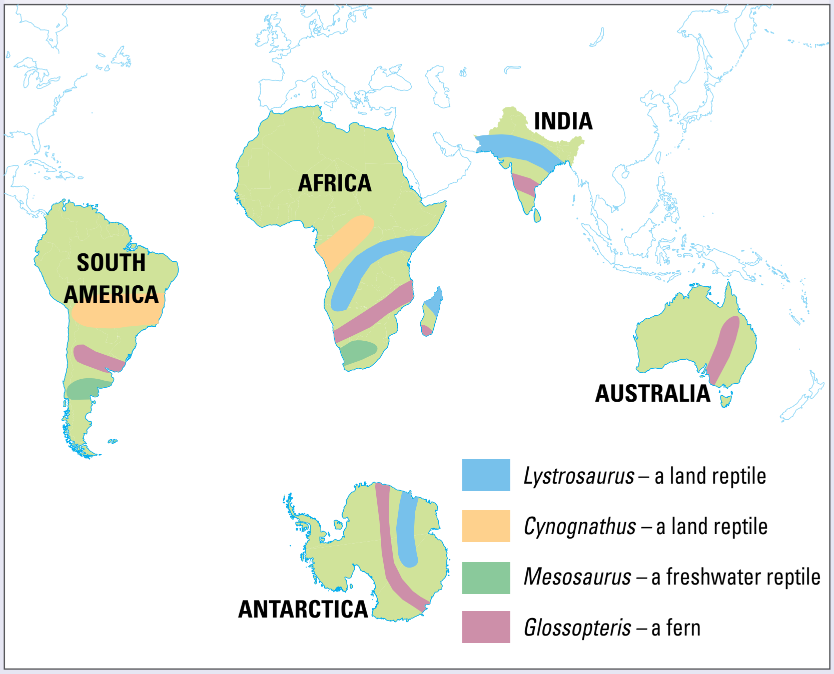
1. Once you have rearranged the continents for your model, glue them into your logbook.
   a. What continent aligns with the east side (right side) of South America?
   b. Is there a continent along the southern margin of Australia?
2. Note which continents must be rotated from their modern-day positions.

Discussion

1. What is the reason for using the distribution of land-based fossils as evidence of Wegener's theory of continental drift?
2. What part of Pangaea does your landmass represent?
3. What latitude and climate conditions during the time of Pangaea would you predict for Australia? How could you investigate your hypothesis?

4. How valid do you think your results are? (*Hint:* compare your result with others around you; did everyone come up with the same configuration? Is there more than one possible configuration?)
5. Suggest at least one other line of evidence that you could look for that would strengthen your results.

Distribution of a selection of fossils of ancient organisms



Conclusion

Using the current shape and position of the continents, what can you conclude about continental drift?

on Resources

eWorkbook Continental drift (ewbk-4479)

assess**on** Additional automatically marked question sets

8.2 Exercise

learn**on**

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

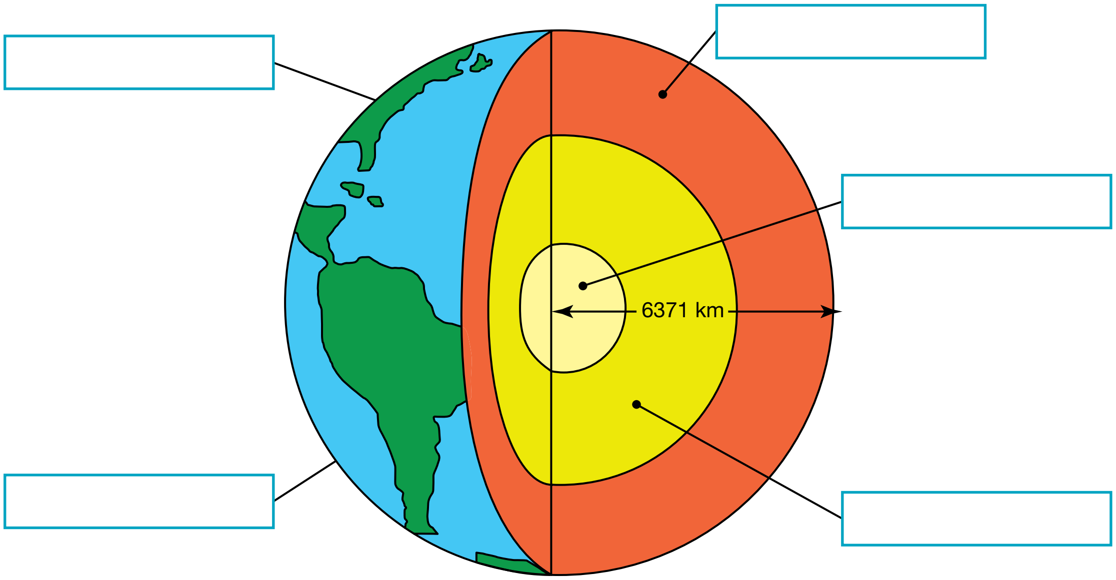
LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 7	Questions 3, 4, 6, 10	Questions 5, 8, 9, 11

Remember and understand

1. Complete the table.

Layer	Description
Atmosphere	
Hydrosphere	
Crust	
Mantle	
Outer core	
Inner core	

2. Provide the appropriate labels for the model of the Earth below (*don't forget about the two different types of crust*).

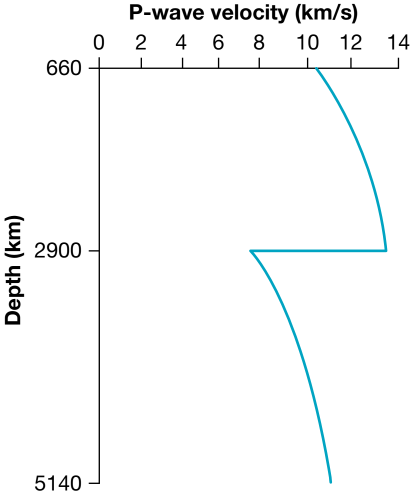


3. Even though the inner core is hotter than the molten outer core, it is solid. Explain why this is the case.
4. How is oceanic crust different from continental crust?
5. Describe two observations that provided evidence for Wegener's theory of continental drift.
6. According to Wegener's theory of continental drift, upon which layer of the Earth are the continents floating?
7. What were Pangaea and Panthalassa?

Apply and analyse

8. How might the study of meteorites improve our understanding of the Earth's interior?
9. **SIS** Seismic waves travel fast in kilometres per second (km/s). The velocity changes of a seismic wave is graphed for the depths around the mantle–core boundary within the Earth as shown in the graph.
   a. Mark the boundary between mantle and core.
   b. What variables can influence the speed of the seismic wave?

Velocity of seismic waves around mantle–core boundary



Evaluate and create

10. **SIS** The Shrinking Earth theory was popular during the 1800s to explain the existence of continents and mountain ranges.
    a. Outline how it explained the existence of continents, particularly mountain ranges.
    b. Suggest an investigation that could help test the theory.

11. SIS Alfred Wegener's theory of continental drift was not widely accepted, despite all the evidence put forward. Review the theory and suggest a reason why the scientific world may have had a hard time accepting continental drift, as he proposed it.

Fully worked solutions and sample responses are available in your digital formats.

8.3 The theory of plate tectonics

LEARNING INTENTION

At the end of this subtopic you will be able to explain how sea-floor spreading works and its importance to the theory of plate tectonics, and you will be able to recognise different plate boundaries and their features.

8.3.1 Mapping the sea floor

Alfred Wegener's theory of continental drift was not widely accepted at the start because it failed to explain how the continents moved. It wasn't until the 1940s, when additional information from the sea floor was gathered that the story started to piece together.

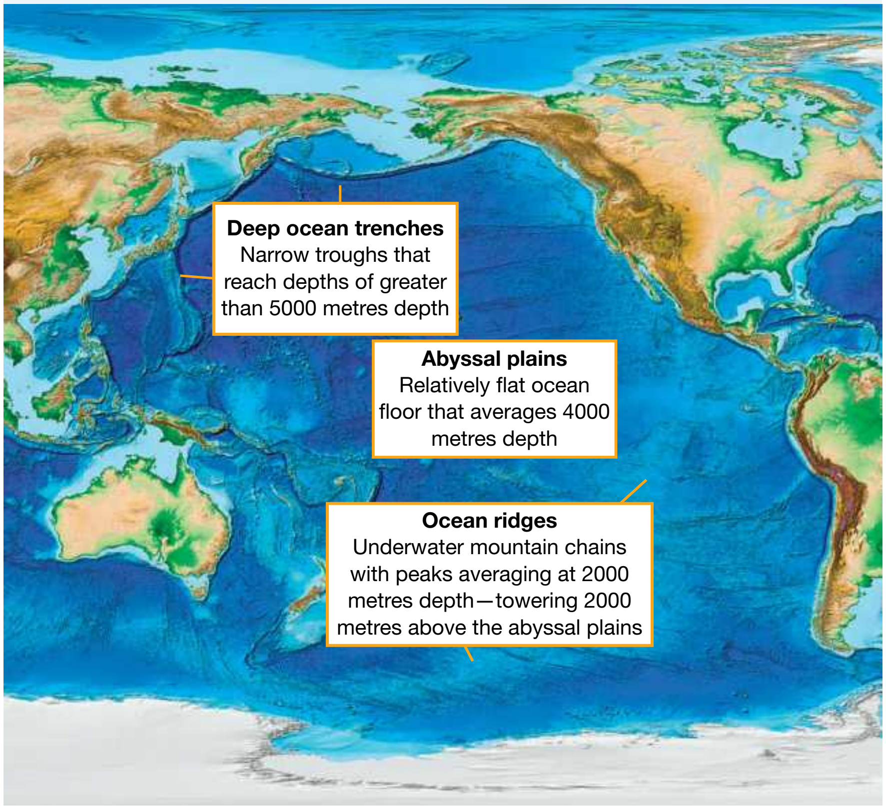
During World War II submarines were used as a defensive tool. They used echo-sounding to avoid collisions and search for other submarines. Harry Hess, a United States naval officer and marine geologist, took advantage of the echo-sounding to also survey and map the ocean floor. He discovered some unexpected features: **abyssal plains**, **ocean ridges** and **deep ocean trenches**.

abyssal plains relatively flat underwater deep ocean floor, around 4000 metres depth

ocean ridges submarine mountains that tower 2000 metres above the abyssal plains

deep ocean trenches narrow and deep troughs in the ocean floor, generally greater than 5000 metres depth

FIGURE 8.5 This topographic model of the Pacific Ocean highlights sea-floor features such as abyssal plains, ocean ridges and deep ocean trenches.

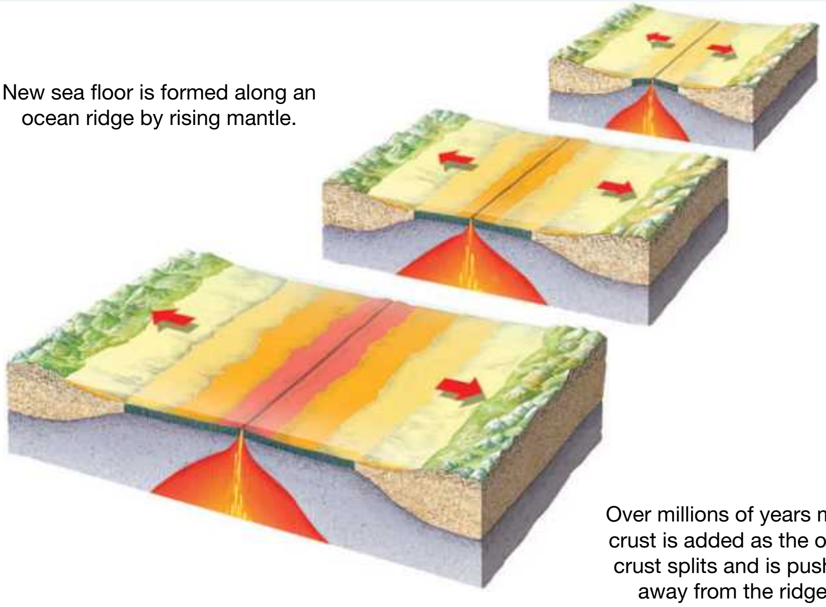


The Mariana Trench of the western Pacific is the deepest place on Earth with a depth of 10.9 kilometres — deep enough to swallow Mount Everest without a trace.

By the 1960s, much of the ocean floor had been mapped, and geologists had gathered more information about the oceanic crust. For example, they discovered *that the rocks further away from the ocean ridges are older and colder than those closer to the centre*. The new data from the ocean floor led to the hypothesis of **sea-floor spreading**.

The hypothesis of sea-floor spreading states that new oceanic crust forms at the centre of ocean ridges as mantle rises, melts, and erupts through underwater volcanoes and then cools again. The new crust then splits in half to allow even younger crust to form in the middle. This pushes the older crust away from the ridges. With time, sea-floor spreading will make an ocean basin wider as more crust is made.

FIGURE 8.6 The process of sea-floor spreading can move continents apart.



DISCUSSION

If the Earth's size and volume do not change, is there a problem with new crust continually being made at ocean ridges? Formulate an idea or hypothesis that could solve this problem.

8.3.2 Theory of plate tectonics

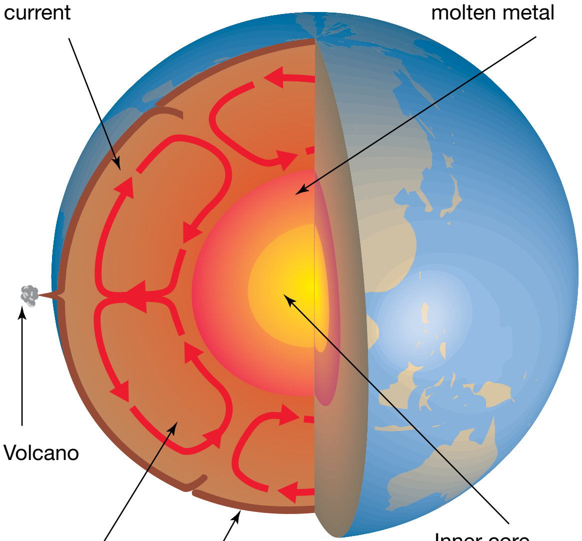
The theories of continental drift and sea-floor spreading paved the way for the more recent theory of **plate tectonics**. This theory proposes that the Earth's crust is broken into pieces, called plates, that move around and interact with one another (tectonics). The theory of plate tectonics explains much more than the movement of continents; for example, it explains why the Himalayas have grown to such great heights, why Iceland is slowly splitting in two and why new rock is being formed along ocean ridges.

sea-floor spreading the formation of oceanic crust, which occurs by the rising and melting mantle at ocean ridges that push older crust away from the ridge

plate tectonics a scientific theory that describes the relative movements and interaction of plates of the Earth's crust over the underlying mantle

The centre of the Earth is hot. When the world formed about 4.5 billion years ago, the whole planet would have been one big ball of **magma**. After all this time you might expect it to have cooled to become a solid ball of rock. However, the Earth is **radioactive**. Heavier atoms like uranium break apart releasing particles that are absorbed by the rock surrounding them. This heats the rock so that the core of the Earth is hot enough to keep the rock in a liquid state. As the centre is hotter than the outside, heat will flow by **convection currents** upwards (figure 8.7). You experience convection currents daily. Boiling water or feeling the wind blow are all convection currents, where heated material is moving from warmer or higher-pressure conditions to cooler or lower-pressure conditions.

FIGURE 8.7 Convection currents in the mantle



The convection currents within the mantle form due to thermal expansion and contraction of rock.

- Heat causes the rock in the mantle to expand, which helps it to rise towards the surface. This in turn pushes on the crust, slowly moving the continents around.
- At the top of the mantle, the rock cools and contracts encouraging it to sink under the force of gravity, where it can heat up and rise again.

This process of the plates sliding over a weak layer of slow-flowing rock in the mantle is called plate tectonics. It is the largest convection current on the planet!

The plates can consist of only continental crust or oceanic crust or be a combination of both. In any case they move slowly (usually just a few centimetres in a year), and can move away from each other, push against each other, or slide past each other.

Topic 9 discusses how and why convection currents form, and the importance of convection currents in the mantle for life on Earth.

magma extremely hot liquid or semi-liquid rock within the mantle. When it erupts on the surface of the Earth it is called lava.

radioactive atoms are unstable and will emit a particle to remove excess energy. These particles are capable of ionising other atoms upon collision, which can cause harm to living tissue.

convection currents the movement of particles in a liquid or gas resulting from a temperature or density difference

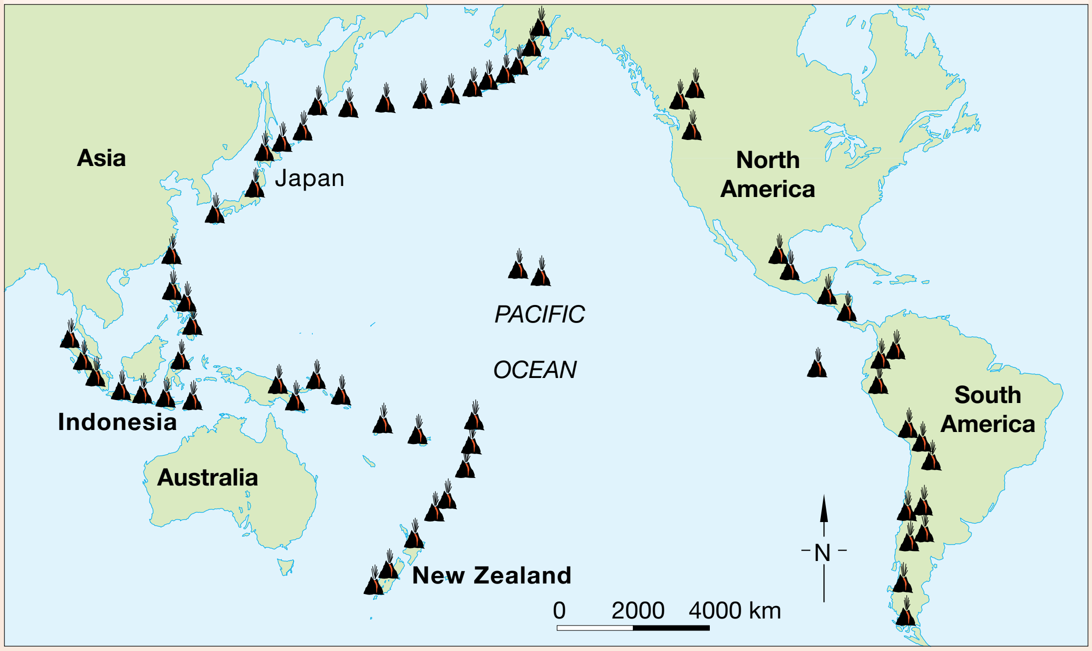
WHAT DOES IT MEAN?

The word *tectonic* is derived from the Greek word *tektonikos*, meaning 'builder'.

CASE STUDY: The Pacific Ring of Fire

The majority of the world's active volcanoes are not random; they lie along a circle around the Pacific Ocean that is known as the Ring of Fire. Why do you think volcanoes are organised like this?

FIGURE 8.8 The Ring of Fire



Plates coming together

When two plates move towards each other we call them converging plates, or a **convergent boundary**, and two convergent scenarios are observed.

1. **Subduction** occurs when old oceanic crust converges towards continental crust or younger oceanic crust. Here, the older oceanic crust is heavier and sinks beneath the other crust to form **deep ocean trenches** (figure 8.9, left-hand image). This is a destructive plate boundary because ocean crust enters the mantle. This movement causes powerful earthquakes and creates arcs of **volcanoes** that are parallel with the deep ocean trenches. The Ring of Fire is a circle of subduction convergent boundaries.
   As time progresses, this subduction can lead to a collision with another continent as they are brought closer together (figure 8.9, center image).
2. **Collision** occurs when subduction brings two continents together. Here, both continents are light and thick, which prevents them from entering the mantle. Instead, huge **mountain ranges**, like the Himalayas, are formed as the continents crumple together figure 8.9, right-hand image). The Himalayas are the result of the collision of the Indian continental plate and the Eurasian continental plate.

convergent boundary where two tectonic plates move towards each other

subduction a convergent plate boundary where one plate moves under another

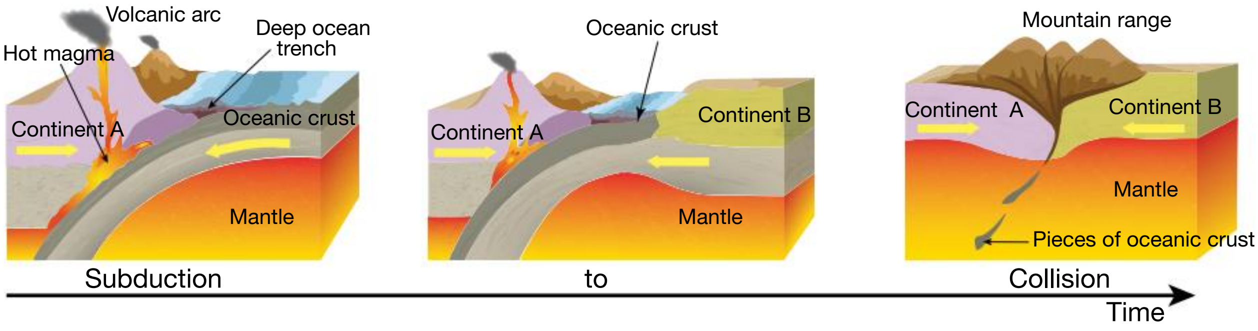
deep ocean trenches narrow and deep troughs in the ocean floor, generally greater than 5000 metres depth

volcanoes a landscape feature through which melted rock is erupted onto the Earth's surface

collision when two continents crumple together to form a mountain range

mountain range a group of high ground features, commonly the result of tectonic collision

FIGURE 8.9 Convergent boundaries from subduction of oceanic crust beneath continental crust through to continent–continent collision, which forms mountain ranges



Plates moving apart

Divergent boundaries are when plates are diverging or moving apart. As they move apart, hot mantle rises to fill in the middle and partially melts because of a decrease in pressure. The melt continues to rise and forms small volcanoes along the divergent boundary; as it cools and solidifies, new oceanic crust is created. Because of the emergence of new crust, these boundaries are known as **constructive plate boundaries**.

divergent boundary where two tectonic plates move apart

constructive plate boundary where new crust is formed

Sea-floor spreading is an example of diverging plates and the centre of an ocean ridge is the divergent boundary between plates. The most famous divergent boundary is the Mid-Atlantic Ridge (figure 8.11), which is spreading apart at 2.5 cm per year or 25 km in a million years! Sea-floor spreading over the past 100–200 million years has caused the Atlantic Ocean to grow from a small body of water between Europe, Africa and the Americas, to the enormous ocean it is today.

FIGURE 8.10 Divergent boundary: the spreading sea floor

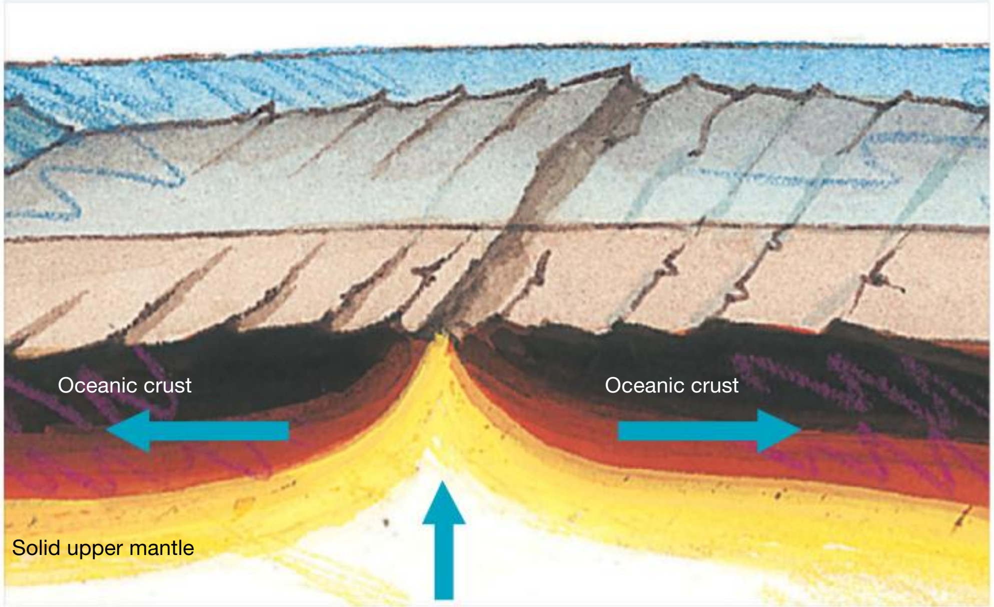
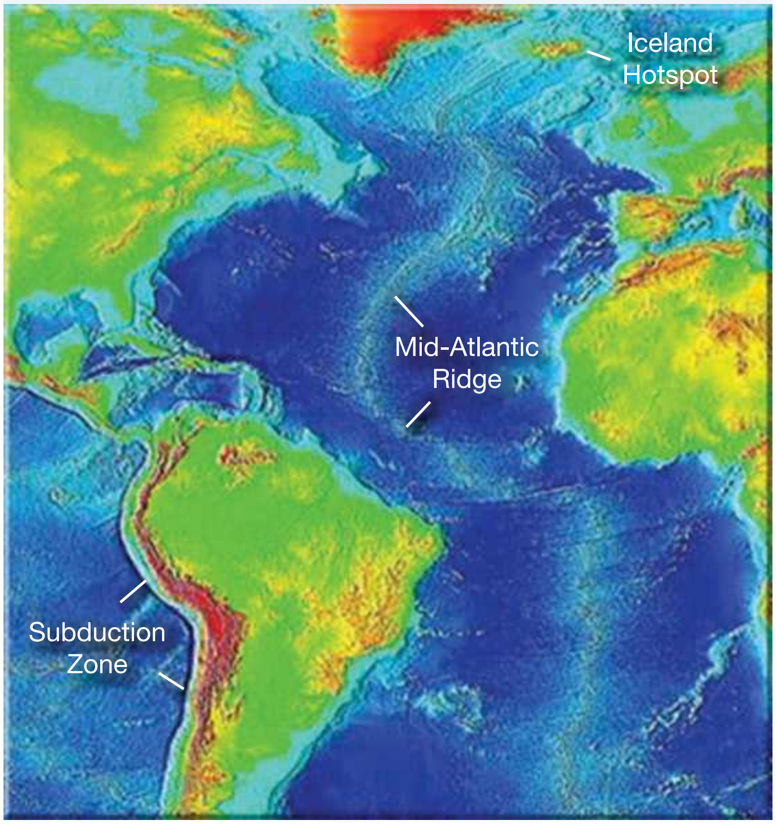


FIGURE 8.11 The Mid-Atlantic Ridge is the largest divergent boundary on Earth.



DISCUSSION

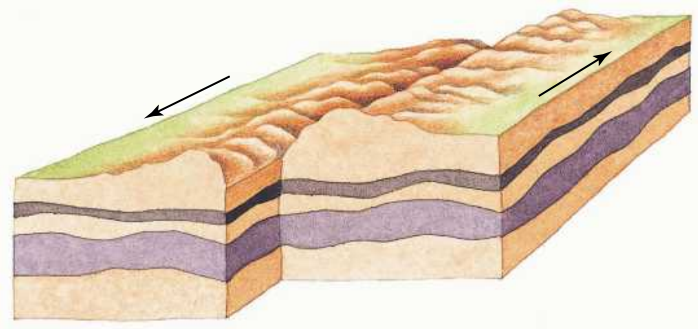
Look at the image of the Mid-Atlantic Ridge (figure 8.11) and locate Iceland. Can you predict why Iceland has so much geological activity? What is causing the volcanic eruptions?

Plates sliding side by side

When two neighbouring plates slide past each other, we call it a **transform boundary**, and earthquakes commonly occur. Large earthquakes occur when something prevents the plates from sliding. Pressure builds up until there is enough force to restart the sliding with a jolt.

The boundaries between sliding plates are known as **conservative plate boundaries**. This is because the crust is conserved (it is neither created nor destroyed). The San Andreas Fault in California, United States, is perhaps the best-known example of a transform boundary.

FIGURE 8.12 Transform boundary: plates sliding side by side



transform boundary where two tectonic plates slide past one another

conservative plate boundary where crust is neither created or destroyed

Resources

Video eLesson San Andreas Fault (eles-4149)

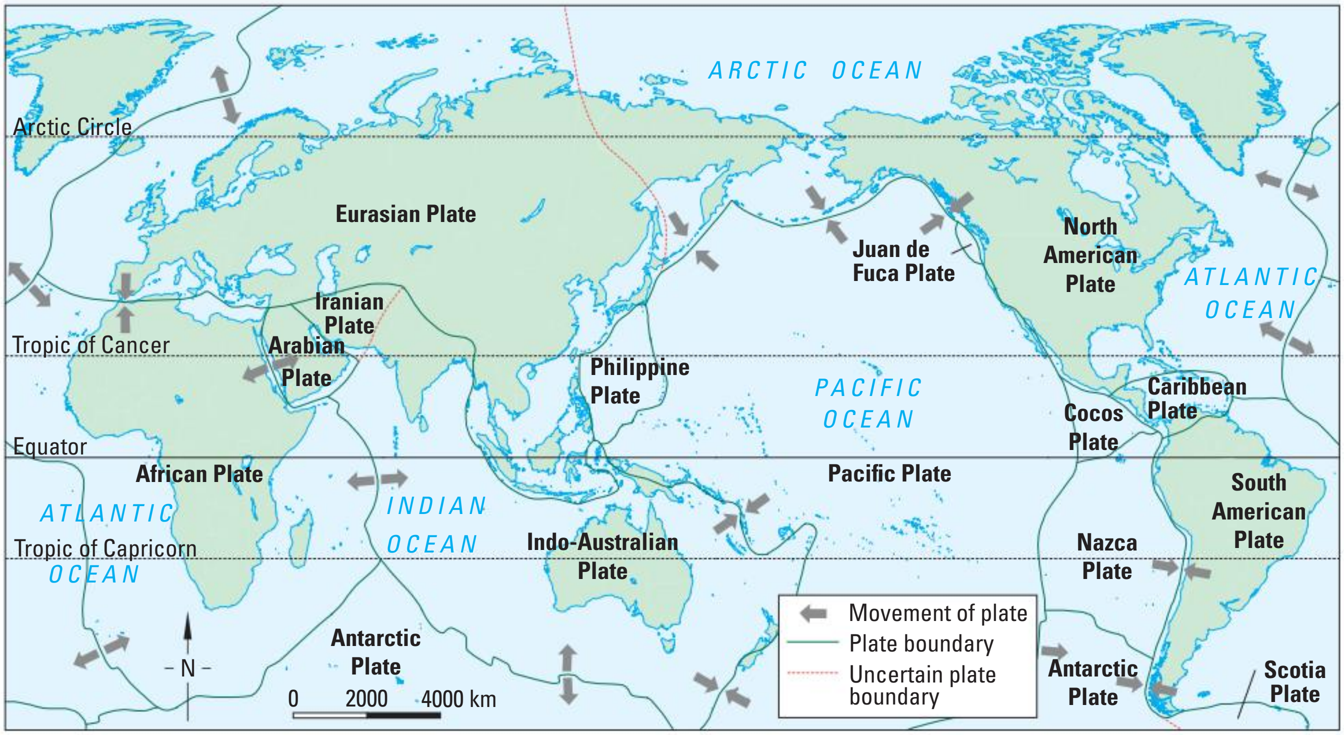
8.3.3 Identifying the current plate boundaries

The major plate boundaries of today can be identified by observing the pattern of volcanoes and earthquakes, and the mapping of spreading ocean ridges and growing mountain ranges. Geologists have directly measured movement of the continents to confirm the plate boundaries.

Geologists have been able to demonstrate that the Earth's crust is divided into over 20 plates, not just the separate continents. Some of the plates are very large, while others are quite small. Figure 8.13 shows the location of some of the major plates and the direction of plate movement. The location of some of the boundaries is still not certain; these are shown on figure 8.13 by red lines.

eles-4150

FIGURE 8.13 A simplified map showing the major tectonic plates that make up the Earth's crust. The arrows show the direction of plate movement.



The Earth recycles itself

While mantle rises and partially melts to form new oceanic crust at ocean ridges, old oceanic crust pushed away from the ridges sinks back down into the mantle at subduction zones. This slow and continuing natural process of 'recycling' old crust and producing new crust takes place over millions of years. But in the process, ocean basins can open and close; and continents get to go along for the ride. The result is that the continents continually shift and reorganise themselves. The configuration of continents we see today is not what it was in the past, and is not what it will be in the future.

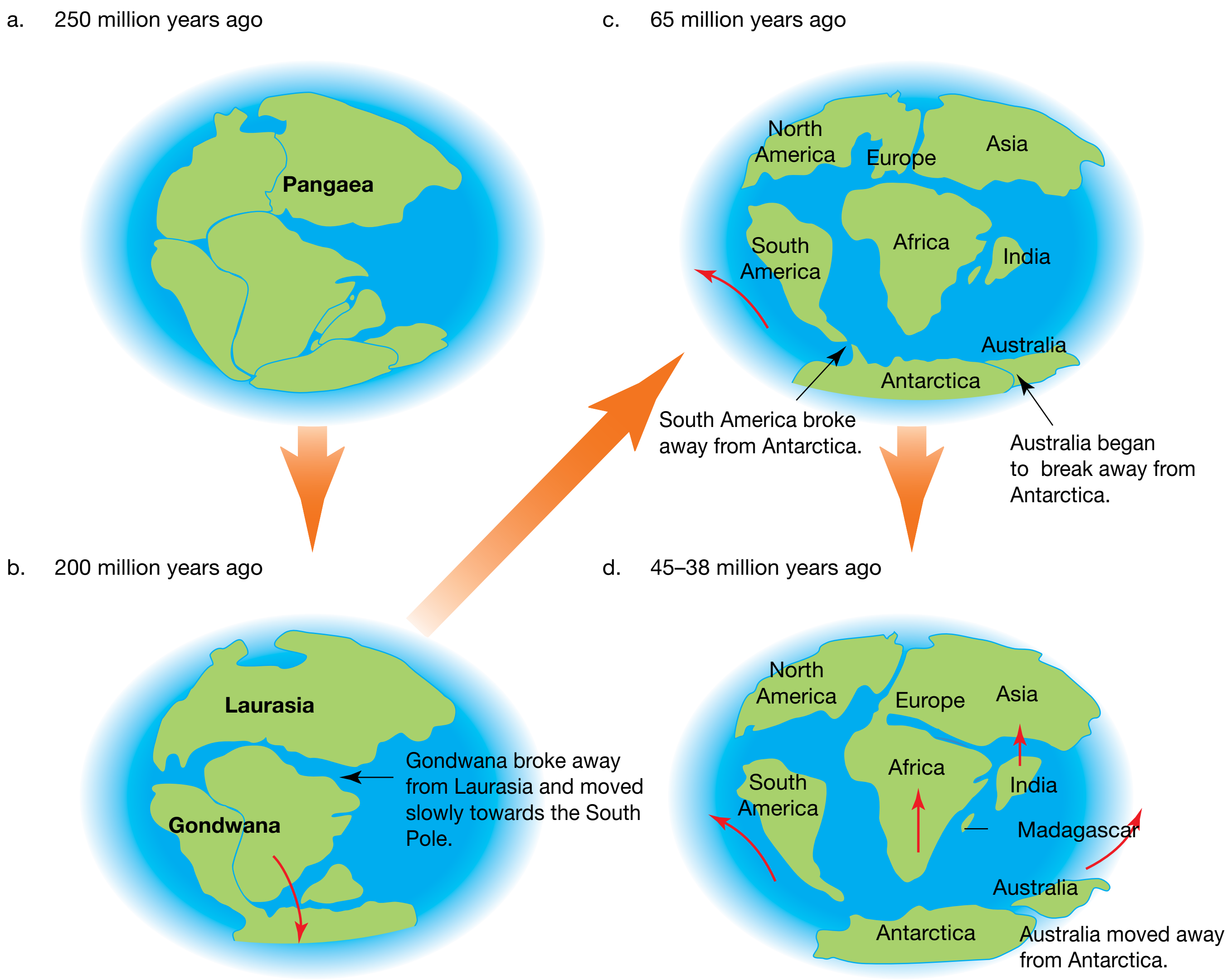
8.3.4 The continental jigsaw

The theory of plate tectonics enabled a more complete reconstruction of the movement of continents proposed by the continental drift theory. Geologists now accept that about 200 million years ago the supercontinent Pangaea broke up into two smaller continents called **Laurasia** and **Gondwana** (or Gondwanaland). The continents of Africa, South America, Antarctica and Australia were all part of Gondwana.

Laurasia the northern part of the broken-up supercontinent of Pangaea, which included the continents of North America, Europe and Asia

Gondwana the southern part of the broken-up supercontinent of Pangaea, which included the continents of Africa, South America, Antarctica and Australia; also known as Gondwanaland

FIGURE 8.14 Two hundred million years ago Pangaea began to break apart, first into two large masses called Laurasia and Gondwana. Which one was Australia a part of?



One of the most famous fossils to support the theory of plate tectonics is from a tree called *Glossopteris*, which has been found across all of the now detached southern continents of South America, Africa, India, Australia, New Zealand and Antarctica. It existed for nearly 50 million years as the dominant plant of Gondwana. Gondwana was named after the region of India where *Glossopteris* was found.

FIGURE 8.15 *Glossopteris* fossils are evidence of the theory of plate tectonics.

SCIENCE AS A HUMAN ENDEAVOUR: Australia on the move

Using high resolution Global Positioning Systems (GPS), geologists have measured that Australia is moving approximately north at 7 centimetres per year. Yes, your house is actually at a different position each year!

Geologists have also rewound time and space to identify that Australia was once connected to Antarctica. Australia began to separate from Antarctica about 65 million years ago. As it slowly moved northward from the polar regions, the landmass experienced climate changes as it moved through different climate zones — from cold, to cool and wet, to warm and humid, and to the hot and dry conditions that most of the continent experiences today.

- How could you distinguish between the global climate changes we are seeing today and those that Australia experiences as it continues its tectonic movement?

A stable continent

Australia is geologically stable because it is near the centre of a tectonic plate, well clear of the boundaries. Volcanic activity and severe earthquakes are unlikely. The extreme age of Australia's rocks is due to its distance from tectonic boundaries, where new rocks may be formed.

on Resources

eWorkbooks	Plate tectonics (ewbk-4554) How does a hypothesis become a theory: Plate tectonics (ewbk-4556)
Interactivity	Does the Earth move? (int-0674)
assess on	Additional automatically marked question sets

8.3 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 4, 6, 7, 8	Questions 3, 9, 10, 11, 13, 15	Questions 5, 12, 14, 16

Remember and understand

1. MC Where does sea-floor spreading occur?
   A. At subduction zones
   B. At convergent plate margins
   C. Along ocean ridges
   D. From undersea volcanoes
2. What tools were used to survey and map the ocean floor during World War II?
3. What is the theory of plate tectonics?
4. If the Earth's surface consists of moving plates, what are the plates moving on?
5. How does rock movement in the mantle help drive the movement of tectonic plates?
6. Which plate boundary are ocean ridges associated with?
7. Describe what happens between plates at these boundaries:
   a. Transform boundary
   b. Divergent boundary
   c. Convergent boundary — subduction
   d. Convergent boundary — collision
8. What is Gondwana?
9. Why does oceanic crust subduct and continental crust does not?
10. Explain why earthquakes are common in the regions surrounding the Himalayas.

Apply and analyse

11. SIS What is the Ring of Fire and why, according to the theory of plate tectonics, does it exist?
12. List, in point form, at least three pieces of evidence that supports the theory of plate tectonics.
13. The illustration represents part of a plate boundary.
    a. Identify the type of boundary present.
    b. Describe the movement of the plates on either side of the plate boundary.
    c. Should this boundary be described as a constructive or a destructive boundary? Explain your answer.

14. The theory of continental drift was first proposed in 1912, over 50 years before the theory of plate tectonics evolved. The evidence for the theory of continental drift also supports the theory of plate tectonics. Explain the difference between the two theories.

Evaluate and create

15. SIS Examine this topographic map of the Indonesian islands and surrounding countries. Focus on the southwestern islands of Sumatra, Java, Bali and Lombok to complete the following.

a. Trace the arc of volcanoes that form on Sumatra, Java, Bali and Lombok.
b. Trace the deep ocean trench in that same area.
c. There have been several earthquakes recently in this region. Identify the type of boundary present that is causing all these earthquakes.
d. Should this boundary be described as a constructive or a destructive boundary? Explain your answer.
e. Present a hypothesis about the tectonics east of Lombok (around Timor, north of Darwin).

16. Explain why the climate of most of the Australian continent has changed from cold to hot and dry during the past 65 million years.

Fully worked solutions and sample responses are available in your digital formats.

8.4 Rocks under pressure

LEARNING INTENTION

At the end of this subtopic you will be able to explain why rocks bend into folds or break into faults when put under tectonic force, and you will be able to identify different types of folds and faults resulting from different tectonic forces.

8.4.1 Rocks under pressure

As the plates that make up the Earth's crust slowly move, solid rock is pushed, pulled, bent and twisted. The tectonic forces on the rocks are huge — large enough to break them, but also large and slow enough to bend them. The forces are concentrated along the plate boundaries but can extend beyond the boundaries.

FIGURE 8.16 Folded layers of limestone in Greece that were formed by tectonic forces

8.4.2 Bending without breaking

If you hold a sheet of paper with one hand on each end and move the ends toward each other, the paper bends upwards or downwards.

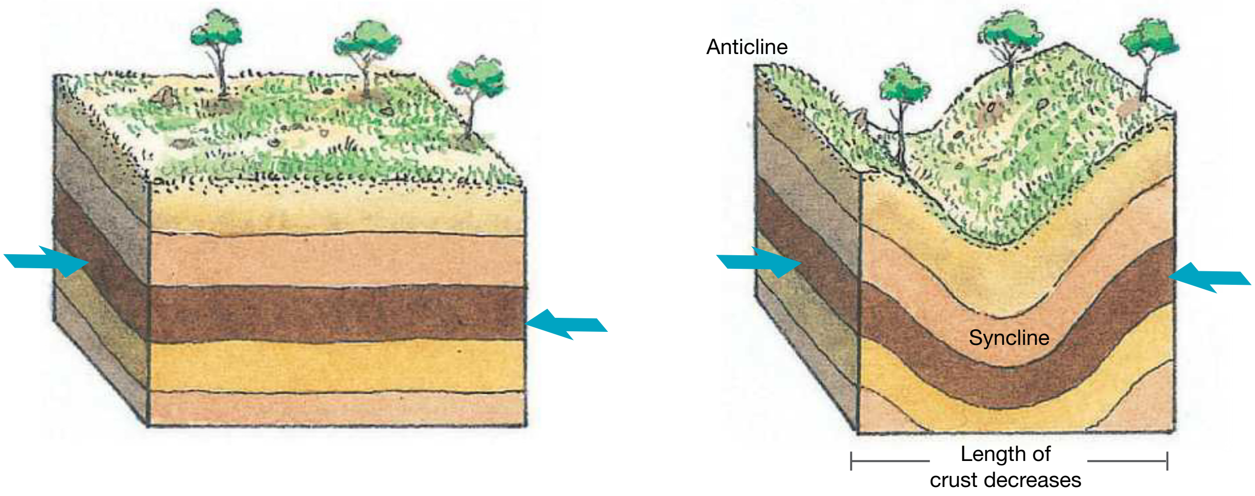
The forces beneath the Earth are so large and slow that layers of rock bend and crumple without breaking, just as the paper does. **Compression** is when a force is applied to a rock and, if this is done slowly enough, will result in the **folding** of rocks. (figures 8.16 and 8.17). Most of the major mountain ranges around the Earth have been shaped by compression and folding.

- **Anticlines** are folds that bend upwards, forming an 'A' shape.
- **Synclines** are folds that bend downwards.

Generally, anticlines and synclines are formed well below the surface of the Earth and are not visible unless they are exposed by uplift and erosion. They can often be seen in road cuttings or in cliffs that have been formed by the erosion of fast-flowing streams.

compression squeezing force
folding when rocks bend into anticlines or synclines
anticline a fold in a rock with the narrow point facing upwards
syncline a fold in a rock with the narrow point facing downwards

FIGURE 8.17 Applying large and slow forces on solid layers of rock can fold them into anticlines (upward arch) and synclines (downward arch).



CASE STUDY: Forming the world's largest mountains

Did you know fossils of ancient sea creatures can be found at the top of the Himalayas, thousands of metres above sea level? How did they get there? We now know that the Himalayas are a convergent plate margin between two continental plates — the Indian Plate and the Eurasian plate — a collision that geologists estimate began around 40 to 50 million years ago. As these plates are both made of continental crust, one plate will not easily slide under the other. Instead, the two are crumpling against each other, forming the mountains. Sediments that once lay at the bottom of the sea between the two landmasses have been forced upward and can be found at the peaks of the mountain range.

The Himalayas are estimated to be rising by more than 1 cm per year as India continues to collide with Asia to the north. This is why the region still experiences shallow earthquakes. However, Earth's gravitational forces as well as the processes of weathering and erosion lower the Himalayas at about the same rate. Mountains on Earth can't grow much higher than Mount Everest, which is about 8840 metres above sea level.

FIGURE 8.18 The folding of rocks is important in the creation of the Himalayas, as two parts of the Earth's crust collide with each other.

elog-0434

INVESTIGATION 8.2

Modelling folds

Rocks are usually folded well below the Earth's surface. The anticlines and synclines can be seen only along road cuttings or where erosion has exposed the layers of rock. A model is a useful way to describe how folded rocks would appear under the surface.

Aim

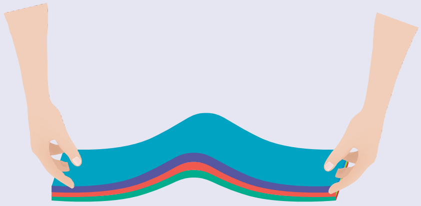
To model the folding of rocks

Materials

- 3 or 4 pieces of differently coloured plasticine
- ruler
- knife or blade or dental floss
- rolling pin
- board

Method

1. Using the rolling pin, roll the individual colours of plasticine into 0.5–1 cm thick layers.
2. Stack the layers of coloured plasticine on top of each other. Press down lightly on the layers, so that they stick together, but not too much as to cause the plasticine to stick to the table.
3. Measure the length and thickness of your model.
4. With the palms of your hands or books on opposite ends, very gently compress the layers from the side by bringing your hands (or books) closer to each other.
5. Measure the new length and thickness of your model.



Results

1. Describe the appearance of the plasticine when the layers are compressed. Include the measure of length and thickness change.
2. Draw a diagram of the plasticine after compression, labelling anticlines and synclines (don't forget a scale).

Discussion

1. Discuss the relationship between the change in length and the change in thickness. Include a link to building a mountain range.
2. Consider why rocks need to be compressed slowly (or gently) to form folds.

Conclusion

What can you conclude about modelling folds? Can you make any connections about changes in length, thickness or even the direction of force?

Extension

Imagine that the rock layers are eroded at the Earth's surface. With the tools provided, model erosion and draw a set of new diagrams of the eroded model, as viewed from above and when viewed from the side.

Where are the oldest and youngest rocks? (Recall the relative age of rock layers with older deposited first.) Is there any relationship between the location of anticlines or synclines and the age of rocks?

8.4.3 Faulting

We have learnt that slow compression forces produce folds, but if the Earth breaks, rather than bends, it produces a **fault**. A number of different forces can produce a variety of faults. These are:

- **compression** — the force of pushing something together
- **tension** — the force of pulling something apart
- **shearing** — the force of smearing or moving something along the side of something else.

These different forces result in different kinds movement, which produce different faults: **reverse**, **normal** and **strike-slip faults**. Reverse and normal faults move rock vertically, whereas slip faults move rock horizontally. Sometimes there is both horizontal and vertical movement, which produces more complicated faults.

In all cases, the movement happens very rapidly and produces earthquakes.

fault a break in the crust where one side moves relative to the other

compression squeezing force

tension a stretching force

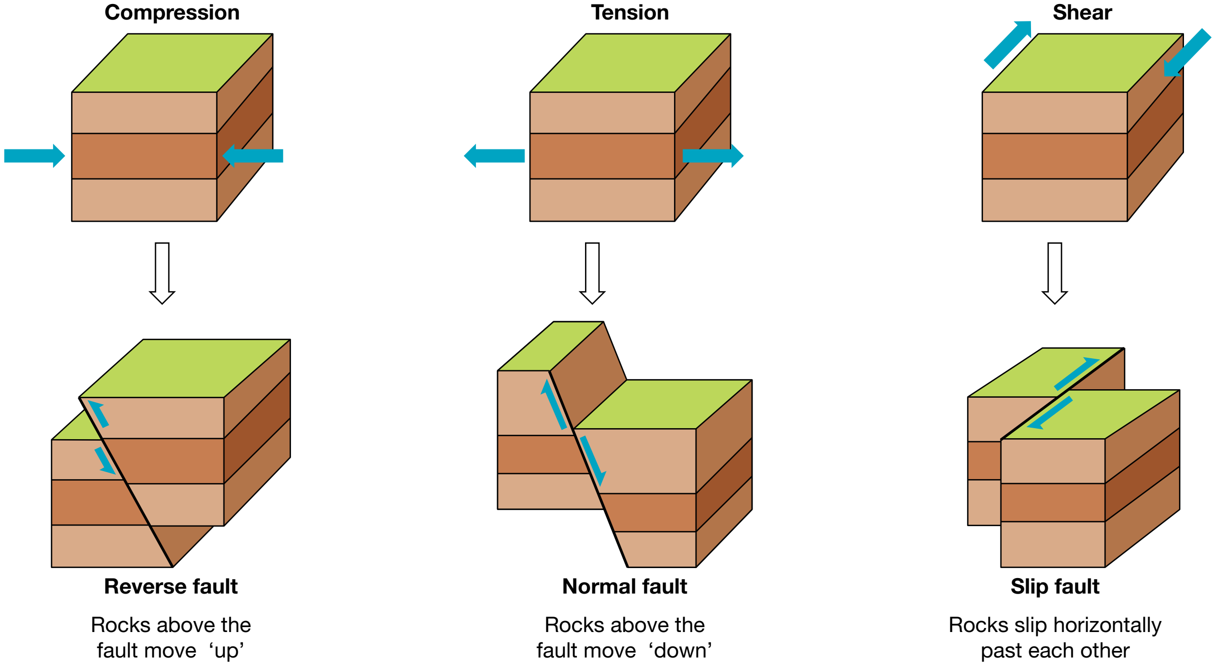
shearing a smearing force

reverse fault a break where the rock above the fault moves 'up' due to compression

normal fault a break where the rock above the fault moves 'down' due to tension

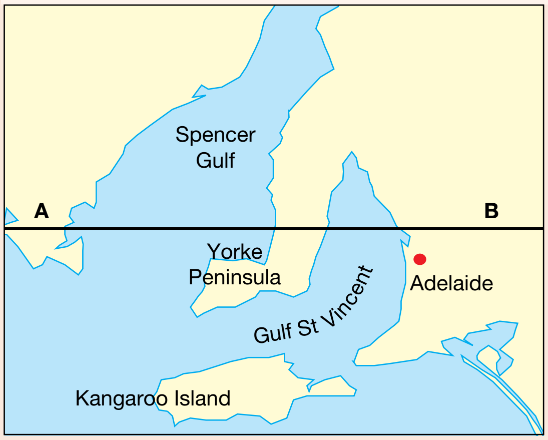
strike-slip fault a break where the rocks on either side of the fault move horizontally due to shearing

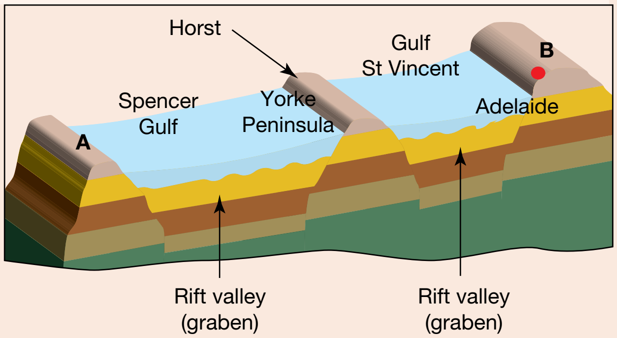
FIGURE 8.19 Compression, tension and shear are different forces. Each produce different types of faults.



CASE STUDY: Forming valleys and mountains in South Australia

FIGURE 8.20 Faulting has shaped the Gulf region of South Australia





The Gulf region of South Australia has been shaped by a series of normal faults. Two blocks of crust have dropped down between faults to form Spencer Gulf and Gulf St Vincent. These sunken blocks are called **rift valleys** or grabens. Between them is a block that is kept at a higher elevation than the rift valleys. This block, called a **horst**, has formed the Yorke Peninsula.

rift valleys a sunken lowland between two normal faults; a graben

horst a highland between two normal faults

What type of force do you think causes horsts and grabens to form?

Occasionally earthquakes are felt in the Adelaide area from movement along these faults, but the movement has changed from when the area was formed. These young earthquakes are the result of compression, which have changed the normal faults into reverse faults!

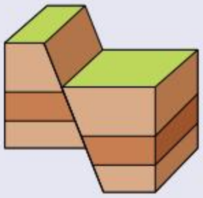
elog-0436

INVESTIGATION 8.3

Modelling faults

Aim

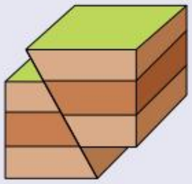
To model normal and reverse faults



Materials

- 3 or 4 pieces of differently coloured plasticine
- a thin sheet of polystyrene
- knife or blade

Method



1. Place the first piece of plasticine on the bench and flatten it into a rectangular shape. Do not make it too thin. Cut a piece of polystyrene the same size and fit it over the plasticine rectangle.
2. Add two or three more layers of plasticine with a layer of polystyrene between each layer.
3. Cut through the layers on an angle as shown in the diagram at right. Use the two parts to model each of the two types of faults shown.

Results

Draw a diagram or photograph each fault. Label it with arrows to show the direction in which each block moved to create the fault.

Discuss

1. Which fault would you expect to find in the Himalaya mountains? Why?
2. Which fault would you expect to find along the oceanic ridges? Why?
3. Propose a method for demonstrating and creating a model for a slip fault.

Conclusion

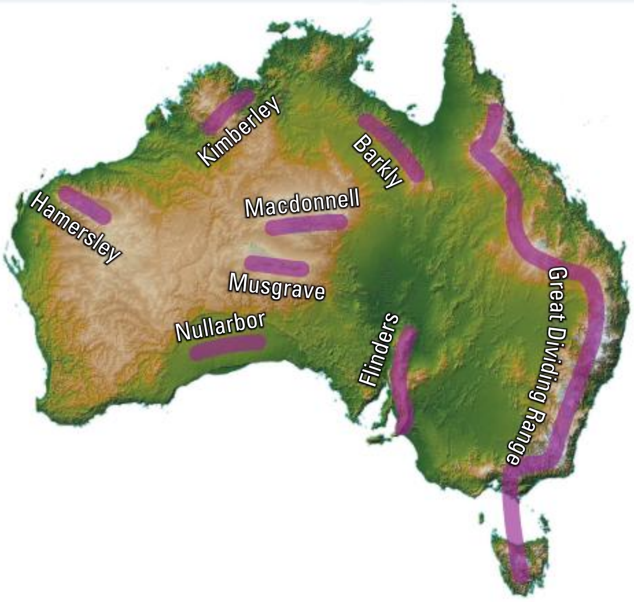
What can you conclude about modelling faults? Can you make any connections about the type of fault, the direction of movement and of the forces applied?

8.4.4 The Great Dividing Range

Australia's Great Dividing Range stretches all the way from northern Queensland to Tasmania. It is actually a chain of separate mountain ranges, including the Carnarvon Range in central Queensland, the Blue Mountains of New South Wales, the Australian Alps, the Dandenong Ranges near Melbourne and the Central Highlands of Tasmania. Forming the Great Dividing Range took two stages:

1. The Great Dividing Range was initially formed by folding and reverse faulting hundreds of millions of years ago. However, over time, it was reduced in height by erosion.
2. Around 80 million years ago, Australia was a part of a splitting Gondwana. The tensional forces pulled the eastern margin of the continent apart, uplifting the western side away from a dropping rift valley on the eastern side.

FIGURE 8.21 Australia's Great Dividing Range is the longest mountain range in Australia.



Resources

eWorkbook Folding and faulting (ewbk-4481)

Weblink The origin of the Australian Alps

assesson Additional automatically marked question sets

8.4 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Why do rocks bend or break?
2. MC When referring to layers of rock, what is folding?
   A. The bending and crumpling of rock without breaking
   B. The breaking and crumpling of rock
   C. The uplifting of super-cooled magma to create rock
   D. The uplifting of rock along a fault
3. What is the cause of folding?
4. Explain the difference between a syncline and an anticline.
5. What are the three different types of forces responsible for developing different fault movements?

Apply and analyse

6. a. Explain the difference between a reverse fault and a normal fault.
   b. Sketch a reverse fault and a normal fault.
7. What causes earthquakes along the San Andreas Fault?
8. SIS There is a lot of faulting as well as folding in the Himalayas. Explain how it is possible for both folding and reverse faulting to develop during mountain building.
9. When the eastern margin of Australia was ripped apart around 80 million years ago, the Great Dividing Range experienced uplift and faulting. What type of faults would you predict dominated this event?

Evaluate and create

10. SIS Explain with the aid of some labelled diagrams how mountains could be formed by faulting.
11. SIS Why don't mountains grow forever? Use Mount Everest as an example.

Fully worked solutions and sample responses are available in your digital formats.

8.5 Earthquakes

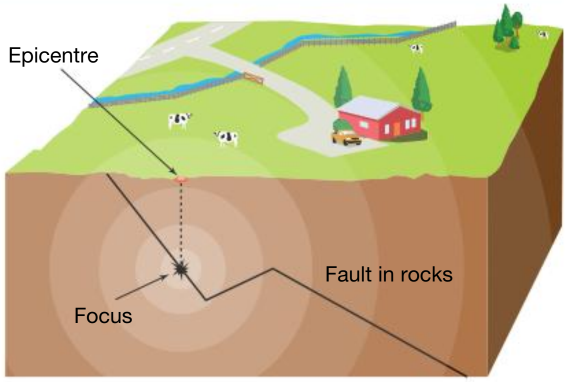
LEARNING INTENTION

At the end of this subtopic you will be able to describe how and where earthquakes form, how they are measured, their potential hazards and their relationship to plate tectonics.

8.5.1 Shake, rattle and roll

Earthquakes result from movements on faults in the Earth's crust. Rocks can only stretch or bend so far before they 'snap', like stretching a rubber band too far. When the rocks 'snap' and move, we get episodes of ground shaking, where the vibrations travel outwards in all directions. Fortunately, most of the vibrations are too weak to be felt. These are called **tremors**. However, when they are strong enough to be felt, they are called **earthquakes**.

FIGURE 8.22 The focus is where the earthquake begins. The epicentre is the surface directly above the focus.



The point at which the earthquake begins is called the **focus**. The **epicentre** of an earthquake is directly above the point below the surface where the movement in the crust began. The epicentre generally experiences the largest vibrations on the surface. However, if the focus is deeper in the crust, the epicentre will experience less vibrations.

Tremors and minor earthquakes can take place wherever there is a fault or weakness in the Earth's crust. Major earthquakes generally occur at or near the plate boundaries where plates are:

- pushing against each other in subduction zones or collisions
- spreading apart at rift valleys or ocean ridges
- slipping and sliding against each other.

tremors minor vibrations of the ground that are commonly not felt

earthquakes a sudden and violent shaking of the ground

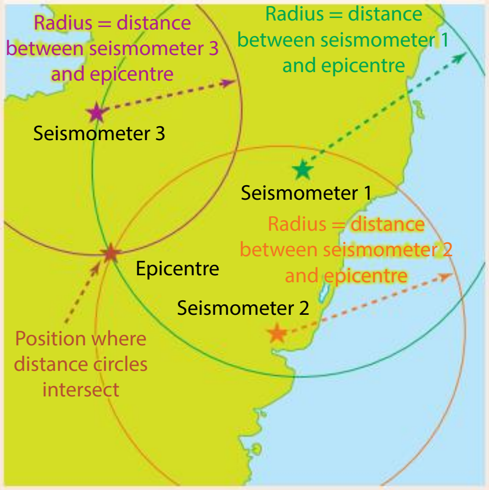
focus the location underground of the fault movement causing an earthquake

epicentre the surface point directly above the earthquake focus

SCIENCE AS A HUMAN ENDEAVOUR: Locating earthquakes

Scientists record earthquake vibrations at seismic stations. The records help to identify how far away the earthquake took place. Records from a single station cannot tell what direction the earthquake came from, because the vibrations travel outwards in all directions. Scientists use a method known as triangulation to determine the position of the epicentre. Triangulation uses, as the name suggests, at least three points to determine the position as shown in figure 8.23.

FIGURE 8.23 Locating the epicentre using triangulation



8.5.2 Seismic waves

Energy released during an earthquake travels in the form of waves. There are two basic groups of waves that are generated by earthquakes: body waves and surface waves.

- **Body waves** radiate outward and travel through the interior of the Earth.
- **Surface waves** tend to travel only along the Earth's surface.

Body waves

Body waves have two kinds of motions.

- **P-waves (or primary waves)** are compression waves (push-and-pull motion), moving through the Earth in the same way that sound waves move through air. They are the fastest of the seismic waves. They can travel through all of the Earth's interior layers.
- **S-waves (or secondary waves)** are the second set of waves, which travel in the form of transverse waves (up-and-down motion). They are second because they are slower than P-waves. S-waves cannot travel through fluids. Because of this characteristic, the outer core was determined to be liquid, because no S-waves have been observed to travel through it.

body waves seismic waves that quickly travel through the interior of the Earth

surface waves seismic waves that travel slower than body waves and only along the surface of the Earth; their energy is lost with depth and distance.

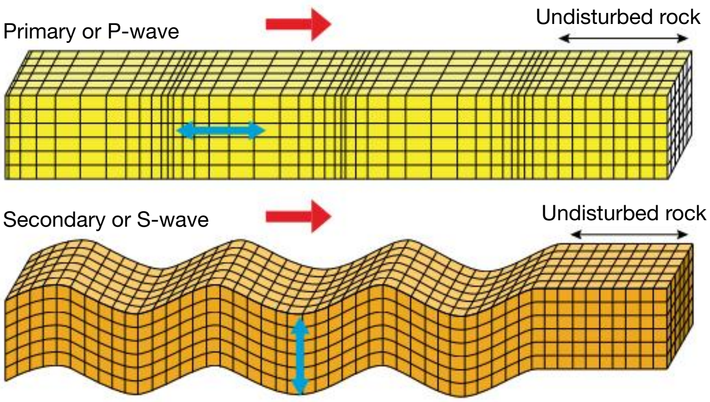
P-waves or primary waves body seismic waves with a compressional (push-and-pull) motion; are the fastest and first to arrive

S-waves or secondary waves body seismic waves with a transverse (up-and-down) motion; are slower than P-waves and cannot travel through fluids

Love waves a surface seismic wave with a side-to-side motion

Rayleigh waves a surface seismic wave that has a rolling motion

FIGURE 8.24 P-waves travel through the earth as compression waves while S-waves are transverse waves.



Surface waves

The surface waves are the *slowest* seismic waves and lose energy with depth and distance travelled. The motions can be complicated, but two types of motions identified are:

- **Love waves** (or L-waves) — transverse waves that move in a side-to-side motion, like a snake
- **Rayleigh waves —** move with a rolling motion like an ocean wave.

These surface waves are responsible for the majority of an earthquake's destructive power. This is because all of the wave energy is distributed across the surface of the Earth rather than being spread out through the Earth's interior like P- and S-waves.

FIGURE 8.25 L-waves travel along the surface with a side-to-side motion while Rayleigh waves have a rolling motion.

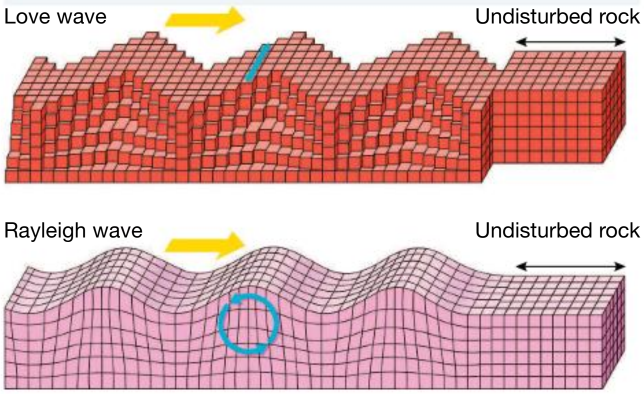
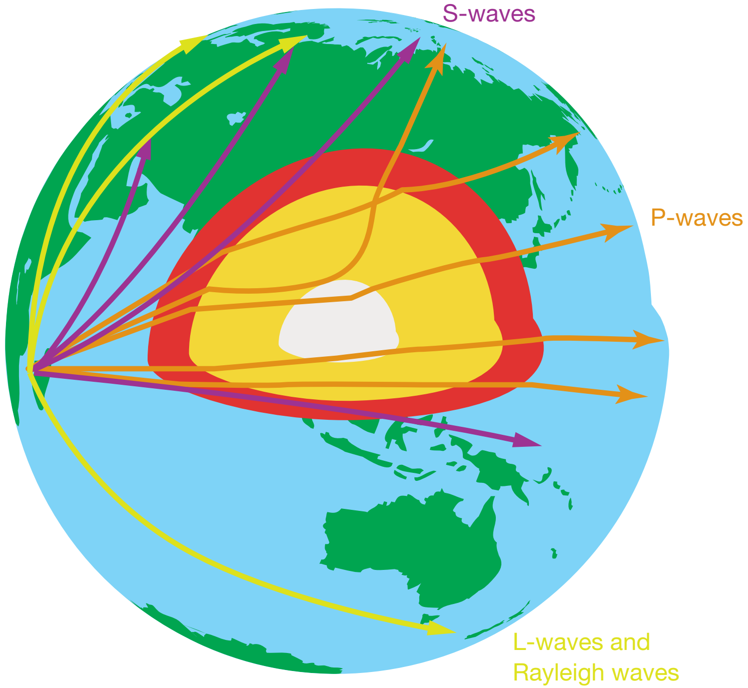


FIGURE 8.26 P-waves are able to travel through all of Earth's interior; S waves cannot travel through liquid, and are thus missing from the outer core; L-waves and Rayleigh waves will only travel along the Earth's surface.



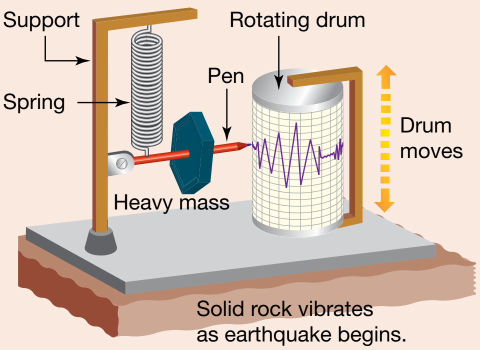
8.5.3 Measuring earthquakes

SCIENCE AS A HUMAN ENDEAVOUR: Measuring earthquakes

Movements in the Earth are recorded with a **seismograph**. Previously earthquakes were measured using a device as shown in figure 8.27, where a strip of paper moves past a stationary pen. The record of an earthquake is shown in figure 8.28. Today, earthquakes are measured using electrical currents to create digital graphs.

The strength of an earthquake can be measured in a number of ways. The most well-known way of measuring the strength of earthquakes is the **Richter scale**. As the different types of seismic waves each travel at different speeds, they are recorded as separate groups on a seismograph. The further apart they are, the further away the seismograph is from the epicentre. Also, the waves record as shorter peaks the further away the seismograph is from the epicentre.

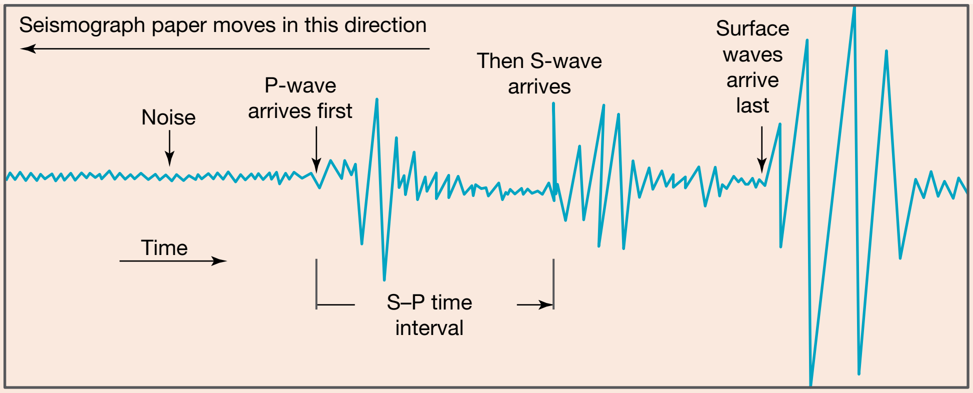
FIGURE 8.27 An earthquake recorded on a seismograph



seismograph an instrument used to detect and measure the intensity of an earthquake

Richter scale a logarithmic scale that measures the amount of energy released during an earthquake, thus allowing one earthquake to easily be compared to another

FIGURE 8.28 Different types of waves travel at different speeds, which allows scientists to tell how far away the earthquake is.



The Richter scale

The Richter scale is a measure of the amount of energy released by an earthquake, and is used to calculate the magnitude (or size) of the earthquake. Scientists determine the magnitude of the earthquake from the amplitude (height) of the surface waves recorded by seismographs.

The Richter scale ranges from 0 to 10, with each increase of 1.0 on the scale representing a *30-fold increase in the amount of energy released*. So, an earthquake of magnitude 6.0 releases 30 times as much energy as one of magnitude 5.0, and an earthquake of magnitude 7.0 releases 900 (30 x 30) times as much energy as one of magnitude 5.0. How much larger is a magnitude 8.0 relative to a 5.0?

Microquakes measure less than 2.0 on the Richter scale and are rarely felt. Earthquakes of magnitude 4.0 on the Richter scale are felt and may even cause objects on shelves or in cupboards to rattle. The largest recorded earthquake was in southern Chile, May 1960, with a magnitude of 9.5.

The Richter scale is not always a good indication of the destructive power of an earthquake. In a crowded city, small earthquakes can cause many deaths, injuries and a great deal of damage, including cutting off water, gas and electricity supplies. Larger earthquakes in remote areas cause few injuries and little damage.

elog-0438

INVESTIGATION 8.4

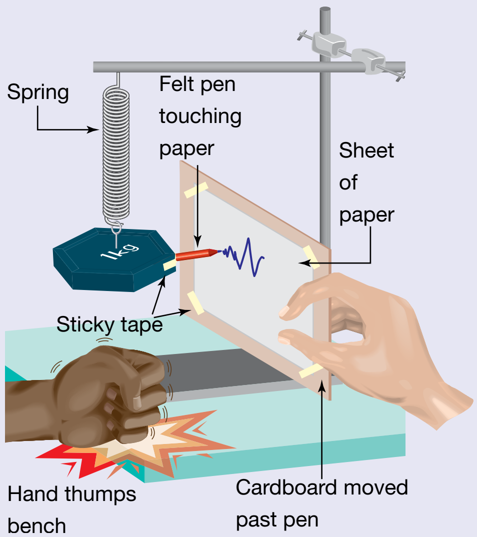
Making a seismograph

Aim

To construct a working model of a seismograph

Materials

- retort stand, bosshead and rod
- spring
- cardboard
- 500 g or 1 kg weight (or a can full of sand)
- sticky tape
- felt pen
- A4 paper



Method

1. Set up the equipment as shown in the diagram.
2. While you thump the surface next to your seismograph, have your partner slide the cardboard past the pen (keeping the board in contact with the table the entire time).
3. Repeat step 2 with a new paper and thumping the table further away from the seismograph (but still the same surface).

Results

1. Title and present your seismograph records.
2. Label where the 'earthquake' is on the record.

Discuss

1. Describe how the model works and how it could be improved.
2. Discuss the difference between the record of thumping closer to the seismometer and that further away. How would that difference affect the validity of evaluating the Richter magnitude from just one seismometer?

Conclusion

What can you conclude about the effectiveness of your model seismograph?

8.5.4 Destructive power

Australia does experience earthquakes, even though it is not on the edge of a tectonic plate boundary. They are called shallow intraplate earthquakes. They are caused mostly by compression coming from the northern and eastern convergent boundaries of the Indo-Australian plate on which Australia sits. This compression can build up within the interior of the plate and be released as earthquakes. There are, on average, 80 earthquakes of magnitude 3.0 or more in Australia each year.

Ground shaking or fracturing by surface waves can cause destruction. The destructive power of an earthquake in any location depends on factors such as:

- earthquake magnitude
- distance from epicentre
- size of population
- type of building materials
- ground type.

For example, the Tennant Creek earthquake of 1988 in the Northern Territory had a Richter magnitude of 6.7; however, only two buildings and the natural gas pipeline were damaged. The epicentre of the earthquake was 40 kilometres north of the town. Yet the smaller earthquake that devastated Newcastle in New South Wales in 1989 registered 5.6 on the Richter scale, killed 13 people, hospitalised 160 others and demolished 300 buildings. The epicentre of that earthquake was only 5 kilometres west of the city.

FIGURE 8.29 In February 2011, a magnitude 6.3 earthquake struck Christchurch, New Zealand. The earthquake destroyed many buildings and homes, injured thousands, and killed 185 people.

DISCUSSION

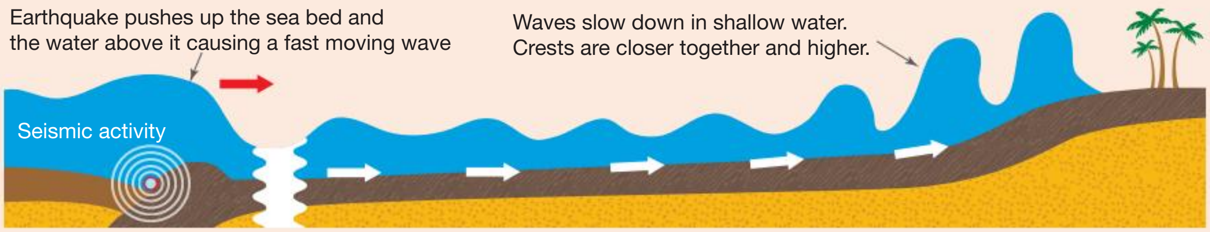
Using the Tennant Creek and Newcastle earthquake examples, discuss what other factors, besides distance from an epicentre, may have influenced the different levels of destruction.

CASE STUDY: Waves of destruction

Earthquakes occurring under the water or near the coast can cause giant waves called **tsunamis**. To form a tsunami, movement on a fault underwater must push up the sea bed, which also lifts up the water above it. This causes huge water waves to form, which travel through the ocean at speeds of up to 900 kilometres per hour. When the waves approach land the water gets shallower. This causes the waves to slow down and build to heights of up to 30 metres.

tsunami a powerful ocean wave triggered by an undersea earth movement

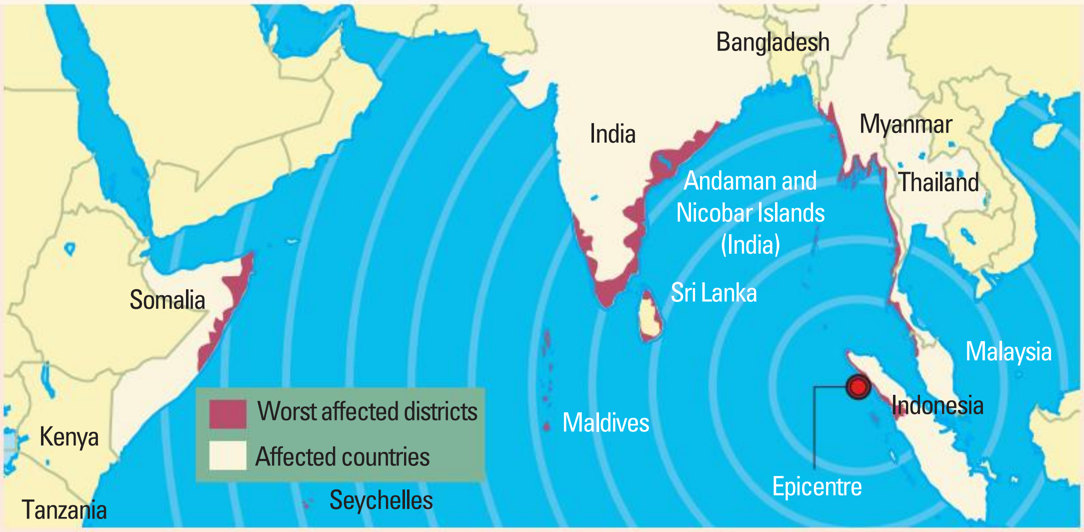
FIGURE 8.30 Illustration of how a tsunami forms



The destructive power of tsunamis became very clear on 26 December 2004 when about 300 000 people died across South-East Asia, southern Asia and eastern Africa. Millions more lost their homes. The tsunami, known as the Sumatra–Andaman tsunami, was caused by a huge earthquake under the ocean floor about 250 kilometres off the coast of the Indonesian island of Sumatra. The earthquake measured 9.0 magnitude on the Richter scale. It pushed a 1000 kilometre-long strip of the ocean floor about 30 metres upwards.

The tsunami flooded 10 kilometres inland near the Sumatran city of Banda Aceh with a 3-metre-high wall of water, mud and debris. Thousands were killed in Sri Lanka, India and Thailand as well. Death and destruction also occurred in Malaysia, Myanmar, Bangladesh and the Maldives. More than 8 hours after the earthquake, the tsunami arrived at the east coast of Africa, more than 5000 kilometres from the epicentre of the earthquake. Even at that distance from the earthquake, the tsunami caused flooding that killed more than 160 people on the coasts of Somalia, Kenya and Tanzania.

FIGURE 8.31 This map shows the huge area affected by the Sumatra–Andaman tsunami on 26 December 2004.



Resources

Video eLesson Tsunami wave propagation during the 2004 Sumatra–Andaman tsunami (eles-4151)

DISCUSSION

The San Andreas Fault in California is a slip fault. It stretches about 1200 kilometres along the coast, passing through San Francisco and to the north of Los Angeles. A large movement of the fault line in 1989 created a major earthquake in San Francisco, killing at least 62 people. The earthquakes experienced in this area in recent years appear to be caused by a build-up of pressure along the fault. Scientists believe that it will not be long before the pressure is relieved through a catastrophic earthquake.

Imagine that you were offered the chance to spend a year at a school in a leafy northern suburb of Los Angeles, just two kilometres from the San Andreas Fault. Would you accept the offer? Explain your response.

SCIENCE AS A HUMAN ENDEAVOUR: Living on the edge

For the people living near the plate boundaries, particularly on the edges of the Pacific Ocean, the ability of scientists to predict earthquakes and tsunamis is critical. The scientists who study earthquakes are called **seismologists**.

seismologist a scientist who studies earthquakes to both understand how they work and how to better predict them

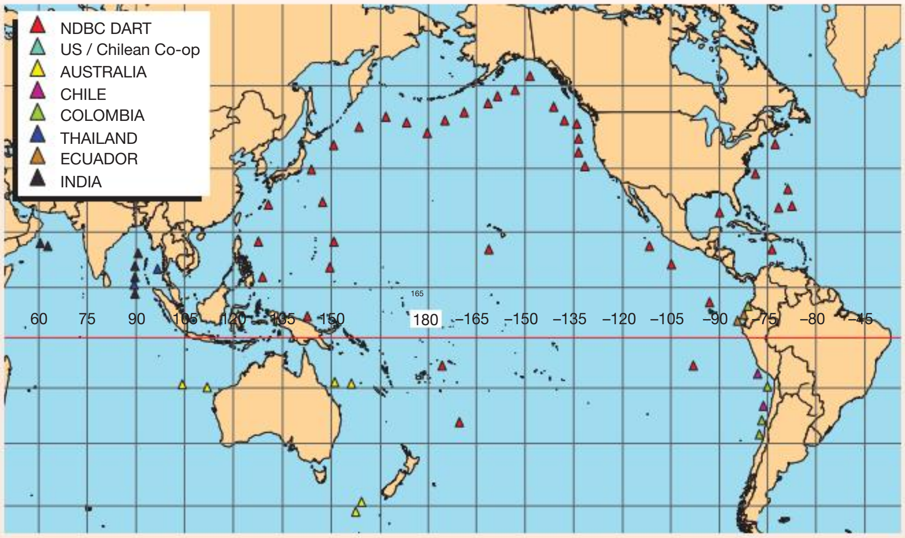
Although it is difficult to predict the time, location and size of earthquakes, seismologists use:

- patterns of past earthquake events to identify the probability of an earthquake of different sizes
- sensors to monitor movement and pressure build-up along plate boundaries and fault lines.

Early warning systems

Tsunami early warning systems rely on the early detection of earthquakes and a system of buoys placed around the Pacific and Atlantic Oceans. This system is called DART (Deep-ocean Assessment and Reporting of Tsunamis). Sudden rises in sea level are detected by the buoys and alerts are sent to tsunami warning centres.

FIGURE 8.32 The locations of DART buoys



The 2011 Japanese earthquake and nuclear meltdown

The world was reminded of the destructive power of earthquakes and tsunamis in March 2011 when an earthquake struck Japan, which was of the same magnitude as the 2004 Sumatra–Andaman earthquake. The epicentre of this earthquake was only 70 kilometres off the coast of the Japanese island of Honshu.

Residents of Tokyo received a *one minute warning* before the strong shaking hit the city. The alerts were received over television but also by text message to mobile phones. The early warning, even a minute, prevented many deaths from the earthquake by stopping high-speed trains and factory assembly lines.

The nearest major city to the epicentre was Sendai, where the port and airport were almost totally destroyed by a tsunami produced by the earthquake. In that city, at least 670 people were killed and about 2200 were injured. Around 6900 houses were destroyed, with many more partially destroyed. Waves of up to 40 metres in height were recorded on the coast and some caused damage as far as 10 kilometres inland.

Several nuclear reactors were shut down immediately following the earthquake that caused the tsunami. However, that wasn't enough to prevent meltdowns in three reactors at the Fukushima Daiichi Power Plant, resulting in explosions and the leakage of radiation into the atmosphere, water and soil (which is described in topic 6).

FIGURE 8.33 Destruction left behind after the 2011 Japan earthquake and tsunami

DISCUSSION

As a class, consider which other countries the 2011 Japan earthquake and tsunami may have affected. Remember to consider the effects of damaging nuclear power stations.

on Resources

eWorkbooks Earthquakes (ewbk-4483)
Plotting earthquakes activity (ewbk-4485)

assesson Additional automatically marked question sets

8.5 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

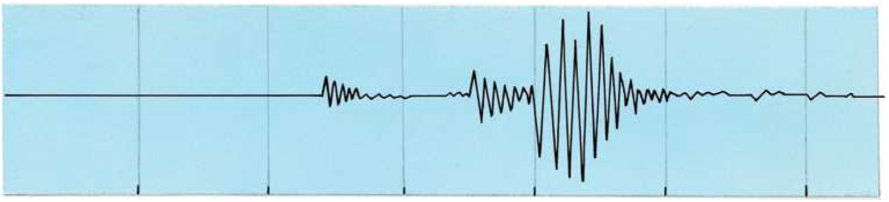
LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 4, 7	Questions 5, 6, 8, 9	Questions 10, 11, 12

Remember and understand

1. What causes earthquakes?
2. Distinguish between an Earth tremor and an earthquake.
3. What name is given to the point at which an earthquake begins?
4. Where is the epicentre of an earthquake?
5. What does the Richter scale measure?

Apply and analyse

6. **SIS** Below is a seismograph, use this image to complete the following.
   a. Label the P- and S-waves.
   b. Label the surface waves.
   c. How would the record look if the seismometer was further away from the epicentre?



7. Explain how seismologists are able to make predictions about the likelihood of an earthquake.
8. Explain why a tsunami only a few metres high in open ocean can reach heights of up to 30 metres by the time it reaches land.
9. **SIS** The table shows the number of people killed in some of the major earthquakes in recent years.
   a. List a pair of earthquakes that provide evidence that the Richter scale does not indicate the loss of life in earthquakes.
   b. What factors, apart from the magnitude, affect the number of deaths in an earthquake?
   c. How much more energy was released by the 2004 Sumatra earthquake than the 2010 Haiti earthquake?
   d. Suggest why there may have been more fatalities during the Haiti earthquake?

TABLE Earthquake year, location, magnitude and fatalities

Year	Location	Number of deaths (approx.)	Richter scale magnitude
1994	Los Angeles, USA	57	6.6
1995	Kobe, Japan	6400	7.2
1999	Iznit, Turkey	17 000	7.4
2001	Gujarat, India	20 000	7.9
2003	Bam, Iran	26 000	6.6
2004	Sumatra, Indonesia	230 000	9.0
2008	East Sichuan, China	90 000	7.9
2010	Haiti (Caribbean Sea)	316 000	7.0
2011	Sendai, Japan	21 000	9.0

Evaluate and create

10. SIS You are requested to measure the magnitude and location of an earthquake; how would you go about each?
11. Explain why Indonesia is more likely to experience major earthquakes than Australia.
12. SIS Earthquakes are mostly generated at depths of 5 to 20 kilometers, where rocks are relatively cool and easier to break; however, they have been measured at depths of up to 670 kilometres.
    a. Which plate boundary would you associate with the deepest earthquakes? Explain your reasoning.
    b. Would you predict these deeper earthquakes to be as destructive as the shallow earthquakes?

Fully worked solutions and sample responses are available in your digital formats.

8.6 Volcanoes

LEARNING INTENTION

At the end of this subtopic you will be able to explain how and where volcanoes form and be able to identify the difference between active, dormant and extinct volcanoes.

8.6.1 Mountains of fire

Although most changes in the Earth's crust are slow and not readily observable, the eruption of volcanoes provides evidence that the changes can also be explosive, fiery and spectacular.

Volcanoes are formed when molten rock from below the Earth's surface, called magma, bursts through a weakness in the Earth's crust. The eruption of a volcano ejects the magma as red-hot **lava** (molten rock flowing on the surface), ash and gas. Most visualise a volcanic eruption as highly explosive with tall clouds of ash. However, a volcanic eruption can vary wildly from highly explosive to calm. A scientist who studies volcanoes is called a volcanologist.

WHAT DOES IT MEAN?

The word *volcano* comes from the name of the ancient Roman god, Vulcan, who was the god of fire.

What comes out?

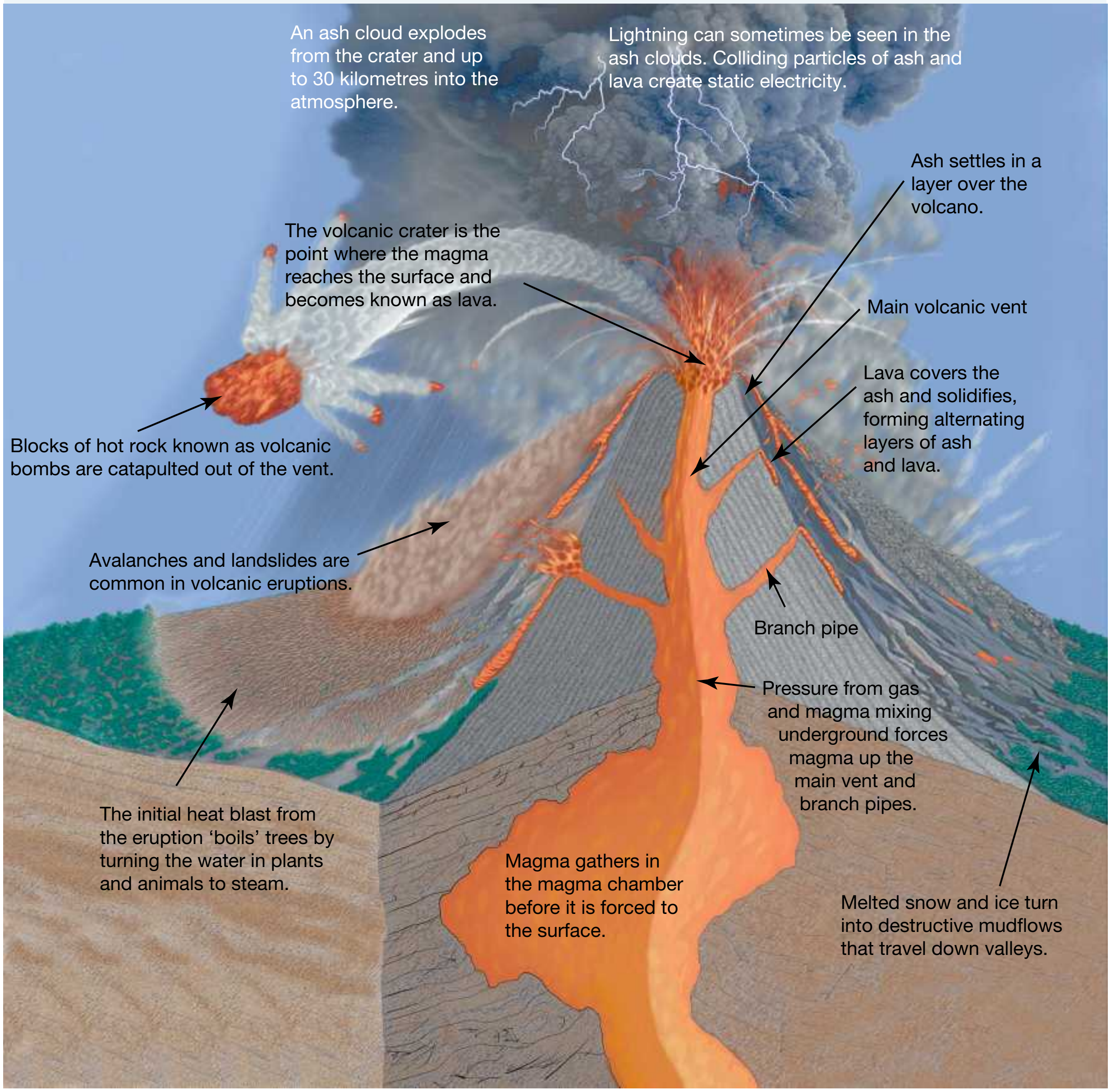
Commonly deep below a volcano is a magma chamber. When the pressure builds up in the magma chamber, steam is the first to emerge from the vents of a volcano. When the volcano erupts, lava flows from the vents and red-hot fragments of rock, dust and ash, steam and other gases shoot out of the crater. The larger fragments of rock blown out of the crater are called **volcanic bombs**. The gases include carbon monoxide and hydrogen sulfide ('rotten egg' gas).

The lava flowing from a volcano can be runny or sticky.
- If it is runny, gas escapes easily, which generally results in a 'calm' or fountaining eruption. It can also flood large areas, cooling to form large basalt plains like those in Victoria's western district as well as in Melbourne, and to the city's north and south.
- If the lava is sticky, it can build up within and on the sides of steep volcanoes and can also block the vents as it cools. When this happens, gases build up in the magma below. As the pressure increases, the volcano can bulge and 'blow its top', thrusting rocks, gases and hot lava high into the air. Exploding gases often destroy part of the volcano.

lava extremely hot liquid or semi-liquid rock from the mantle, which has reached and flows or erupts on the Earth's surface

volcanic bomb large rock fragment that falls from an eruption, formed as lava, is blown out of a volcano and is rapidly cooled in the air

FIGURE 8.34 Parts of an erupting steep volcano formed with sticky lava



on Resources

Video eLesson Volcanoes (eles-0130)

CASE STUDY: Forming a volcano

On a cool winter's day in 1943, a small crack opened in a field of corn on a quiet, peaceful Mexican farm. When red-hot cinders shot out of the crack, the shocked farmer tried to fill it with dirt. The next day, the crack had opened into a hole over 2 metres in diameter. A week later, the dust, ash and rocks erupting from the hole had formed a cone-shaped mound 150 metres high! Explosions roared through the peaceful countryside and molten lava began spewing from the crater, destroying the village of Paricutin. The eruptions continued and, when the eruptions stopped in 1952, the new mountain named Paricutin was 410 metres high.

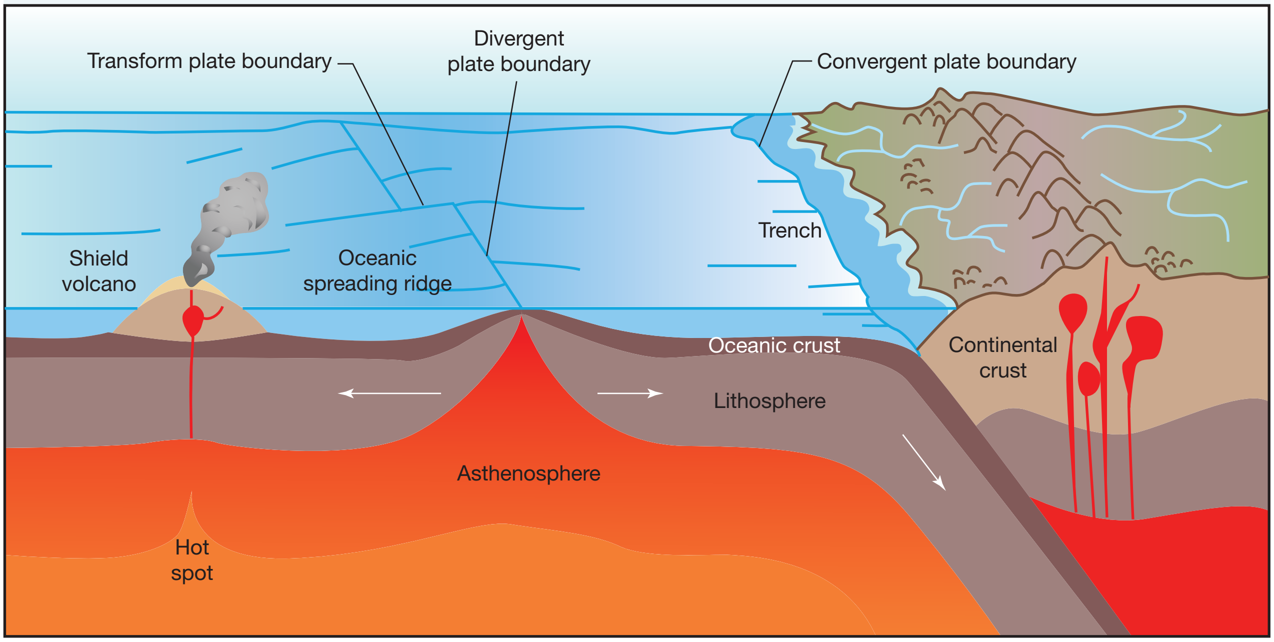
This volcano of Paricutin is one of several volcanoes that string down the western side of Mexico. Why are they there? They are a part of the 'Ring of Fire' that circles the Pacific Ocean, and are formed from the subduction of oceanic crust under continental crust.

FIGURE 8.35 The volcano of Paricutin formed in just 9 years.

The majority of volcanoes on Earth are linked to either:

- subduction zones, like the Pacific Ring of Fire — convergent boundaries where oceanic crust is being subducted beneath another plate
- divergent boundaries — where magma wells up into the spreading centre to create an ocean ridge.

FIGURE 8.36 Volcanism resulting from two different plate boundaries: convergent and divergent plate boundaries. Can you identify a volcano in the diagram that is not related to a tectonic plate boundary?

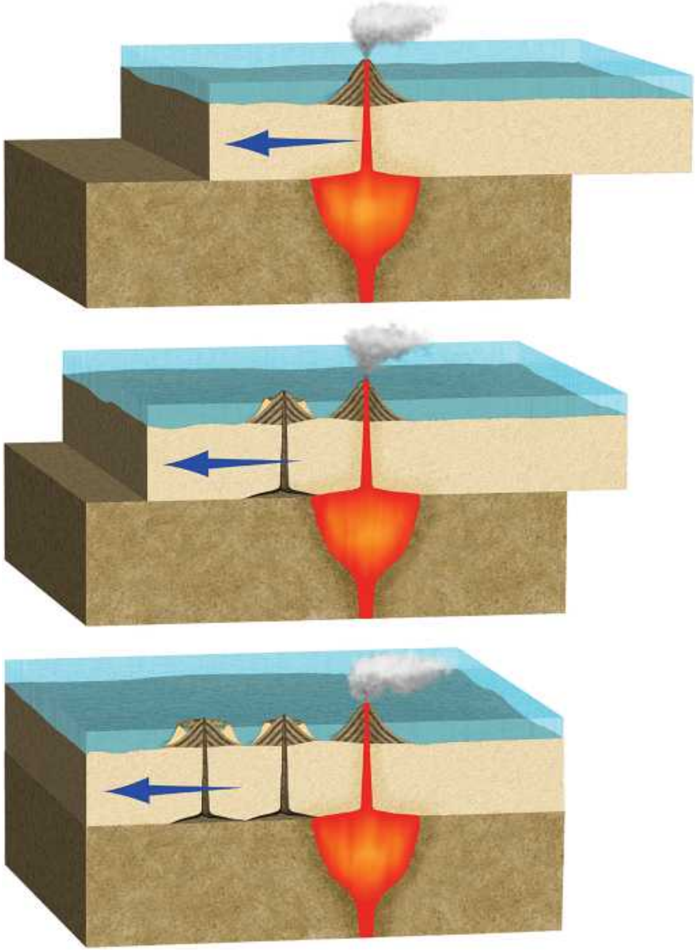


Hotspots

What about the Hawaiian Islands in the middle of the Pacific Ocean? They are clearly volcanic, but don't align with any tectonic boundaries. Although most of the world's volcanoes are found at the edges of the plates of the Earth's crust, some lie over features we call **hotspots**. These hotspots are regions of the crust where the mantle below is extremely hot and magma surges upwards into the crust.

Hotspots create chains of volcanic features that are older the further away they are from the active site of the hotspot. Therefore, *the hotspot is believed to be stationary as the crust moves over it.*

FIGURE 8.37 The formation of a hotspot volcanic chain in the ocean, where the oldest volcanic feature is the furthest away from the hotspot. As the older volcanoes become further away from the source of magma and heat, they erode and sink below the ocean.



Hotspots can form over continents as well. Many of Australia's youngest volcanoes along the Great Dividing Range (less than 80 million years old) were the result of hotspot activity.

Underwater volcanoes

Active volcanoes also erupt under the sea. In fact, an ocean ridge is a continuous belt of volcanoes with **black smokers**. Black smokers are thermal vents on the sea floor, which eject superheated water rich in elements that were dissolved from the ocean crust. Theories suggest that the beginnings of life could have started around black smokers under the ocean.

hotspot a volcanic region directly above an area of anomalously hot mantle

black smoker a geothermal vent on the sea floor that ejects superheated mineral rich water

An active volcano below the sea is generally not visible. However, if layers of lava build up, they may eventually emerge from the sea as a volcanic island. Lord Howe Island, off the coast of New South Wales, was formed in this way about 6.5 million years ago. A more recent example is the island of Surtsey, which emerged from the sea off the coast of Iceland in 1963.

8.6.2 Active, extinct or dormant

Active volcanoes are erupting or have recently erupted. Mount Pinatubo in the Philippines, which erupted in June 1991 killing 300 people, is an active volcano. There was so much smoke and ash coming from Mount Pinatubo that scientists believe that the Earth's weather was cooler for over a year.

Volcanoes that have erupted in the last 10 000 years but are not currently erupting are called **dormant volcanoes**. Dormant means 'asleep' and these volcanoes could 'wake up' at any time and erupt. Mount Pinatubo was a dormant volcano before its eruption in 1991. **Extinct volcanoes** are those that have not erupted for at least 10 000 years. They are effectively dead and are very unlikely to erupt again.

active volcano a volcano that is erupting or has recently erupted
dormant volcano a volcano that has erupted in the last 10 000 years but is not currently erupting. They are considered likely to erupt again.
extinct volcano a volcano that *has not* erupted in the last 10 000 years. They are considered dead and not to erupt again.

DISCUSSION

As a class, or in small groups, list some physical observations you could make about the appearance of a volcano that may help to label it as active, extinct or dormant.

There are many extinct volcanoes in Australia. The Glasshouse Mountains of Queensland are the remains of lava that cooled in volcanic vents. In Victoria, Tower Hill, near Warrnambool, is another example, and there are many others. Mount Gambier in South Australia could be dormant or extinct, as estimates of its last eruption range from over 28 000 to a little less than 5000 years ago. In either case, the craters collapsed and have filled with water to form beautiful clear lakes. Some radiocarbon dating of plant fibres in the main crater suggests the last eruption was a little before 6000 years ago, suggesting more of a dormant status.

FIGURE 8.38 A small crater on the extinct Tower Hill volcano in Victoria

Australia is close to the centre of the Indo–Australian Plate so it is very stable geologically. This is why there are few recent volcanic eruptions and only a small number of earthquakes.

on Resources

eWorkbooks Volcanic activity (ewbk-4558)
Geological activity (ewbk-4560)

Video eLesson Deep-sea mining (eles-1086)

assess on Additional automatically marked question sets

8.6 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. What can cause a volcano to erupt?
2. List the substances that emerge from a volcanic crater during an eruption.
3. Explain the difference between a dormant volcano and an extinct volcano.
4. What is a hotspot?
5. Explain in terms of the plates that form the Earth's crust why Australia experiences little volcanic or earthquake activity.
6. Use a Venn diagram to show the differences and similarities between magma and lava.
7. How do you know that many of the volcanoes in the western district of Victoria had runny lava?

Apply and analyse

8. Explain how a volcano can affect the world's weather.
9. A photograph of the crater at Mount Gambier is shown. Should Mount Gambier be described as an extinct or dormant volcano? Explain your answer.

10. SIS How might you investigate the hypothesis that the volcanic features of the Great Dividing Range formed from a hotspot.

Evaluate and create

11. SIS A volcanologist working for the government is assigned to assess the probability of a volcanic eruption from a local volcanic feature. The volcanologist decides to first map the rocks around the volcano and obtain the ages of these rocks to piece together the eruption history.
    a. Explain why it is important for the geologist to map the rocks and obtain their ages.
    b. Suggest one additional investigation that may improve the final conclusion.

Fully worked solutions and sample responses are available in your digital formats.

8.7 Thinking tools — Double bubble maps

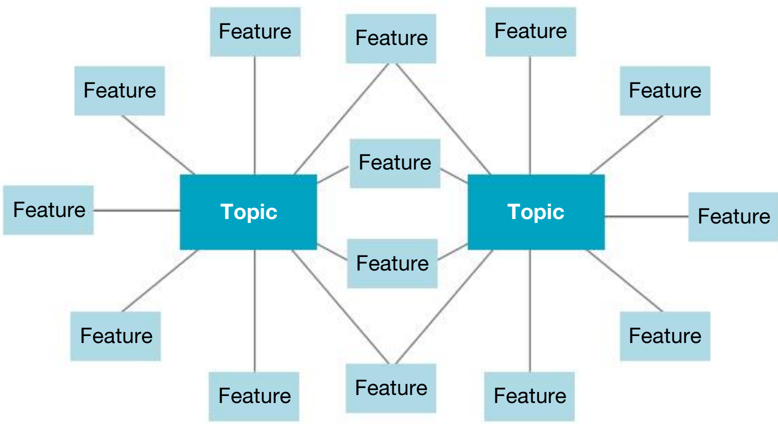
8.7.1 Tell me

What is a double bubble map?

A double bubble map is a diagram that breaks up two ideas or topics into different categories and allows you to compare and contrast them. It shows features that are similar — these are joined to both topics — and features that are different — these are joined to just one topic.

A double bubble map helps you understand how topics can be broken into different categories and the relationships that exist between them. They allow you to make connections between two ideas that have both similarities and differences.

FIGURE 8.39 Double bubble map



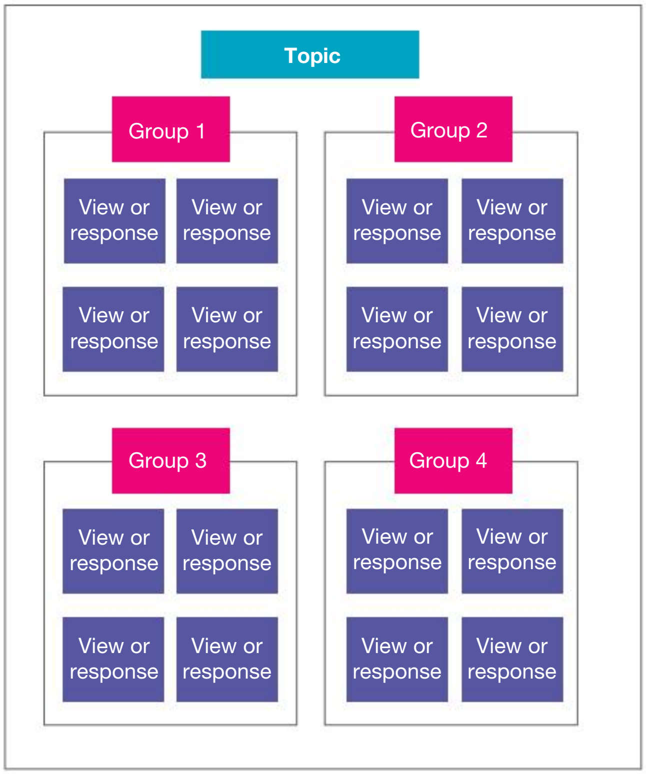
For example, you would use a double bubble map to:

- compare two concepts
- break your ideas down into smaller features
- brainstorm ideas for a project or essay.

Comparing a double bubble map to an affinity diagram

An affinity diagram lets you explore one idea and see how it can be broken into smaller groups. These smaller groups each contain ideas or features that are similar. It can be helpful to think of your topic and then write down all the ideas you have about it on small cards or pieces of paper. You can then move these cards to place them in groups that are similar.

FIGURE 8.40 Affinity diagram

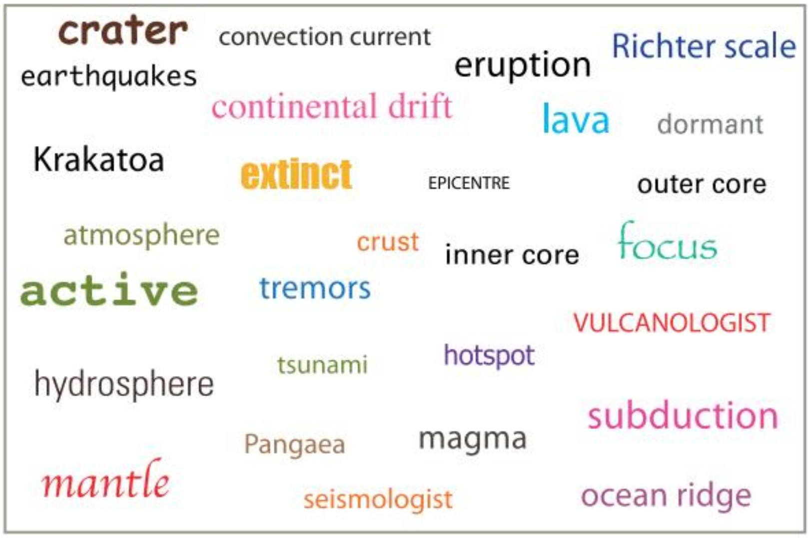


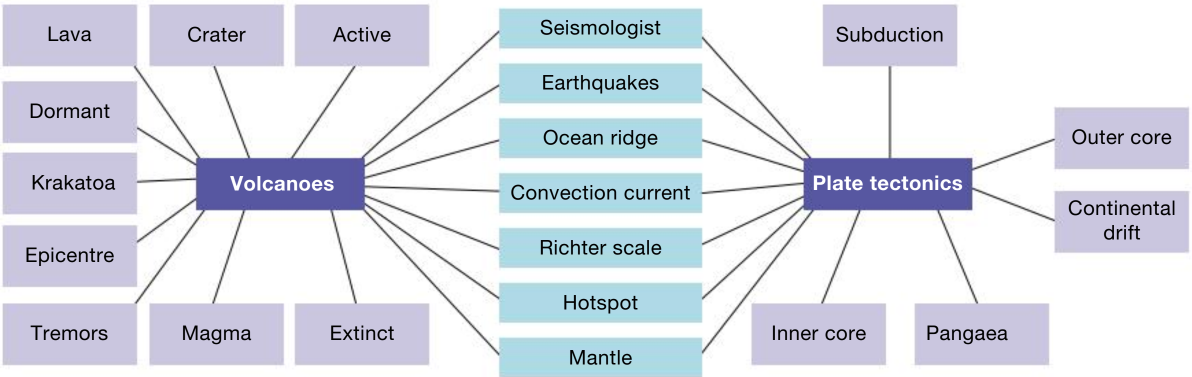
8.7.2 Show me

To create a double bubble map:

1. Choose two topics that are related to each other and write any ideas you may have onto small pieces of paper. For example, you might choose to compare volcanoes and plate tectonics.
2. Examine your pieces of paper and put ideas which only relate to one topic into one group, and any ideas which relate to the second idea in another.
3. Any ideas you have which are related to both topics will now form the middle of your double bubble map.

4. Using these words, you might create a double-bubble map that looks like the example given.





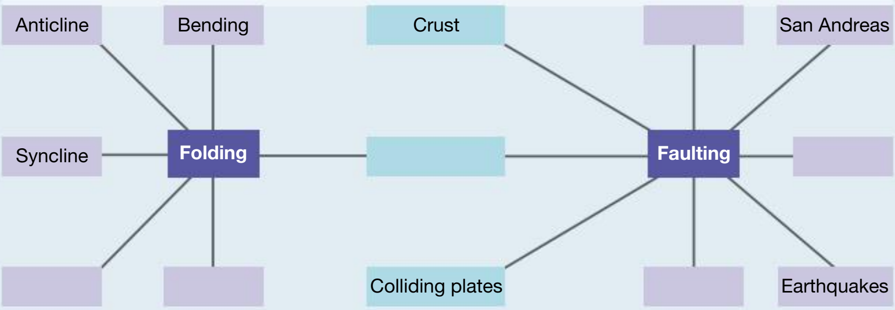
8.7.3 Let me do it

8.7 ACTIVITIES

Create double bubble maps that illustrate the similar and different features of the following pairs of topics:

a. folding and faulting
b. earthquakes and volcanoes
c. continental drift and plate tectonics.

Use this figure to help you get started on a double bubble map for folding and faulting.



Fully worked solutions and sample responses are available in your digital formats.

8.8 Project — Disaster-proof

Scenario

Earthquakes occur when pressure built up between adjacent sections of rock in the Earth's crust is suddenly released. The bigger the earthquake's magnitude, the greater the amount of energy that shakes the Earth. However, the magnitude of the earthquake is not necessarily a good indication of how deadly it will be. The May 2006 earthquake in Java had a magnitude of 6.2 and caused the deaths of nearly 6000 people, yet the 2004 Guadalupe earthquake was the same size but killed only 1 person. In some cases, magnitude 5.3 earthquakes have killed more people than those with magnitude 8.1. In fact, the key predictors other than magnitude of how deadly an earthquake will be are how heavily populated the area is and what type of buildings are there. Sadly, the majority of people who die in earthquakes do so because the buildings around them fail.

Unlike the more earthquake-prone regions of the world, Australia is not near a plate boundary, but we are not out of danger. The 1989 Newcastle earthquake had a magnitude of 5.6 and resulted in 13 deaths, 160 injuries and damage to over 60 000 buildings. With this in mind, your company — Shakeless Seismic Solutions — has been approached by a wealthy client who wishes to build an earthquake-proof five-storey office block in Perth. However, yours is not the only company that she has approached. In order to determine which business she will award the contract to, she is asking each company not only to come up with a design, but also to have a scale model of their design tested on a shake-table earthquake simulator.

FIGURE 8.41 Damage caused by the 1989 Newcastle earthquake

Your task

Your group will use research, ingenuity and online simulators to design a five-storey office block that will survive an earthquake. You will build a scale model of your design and compete with other groups to determine which model/design is able to withstand the most energetic shaking on the simulator. Your model will need to fulfil the following criteria:

- It should have a total mass of no more than 1.5 kg.
- It should have a base area no bigger than 20 cm × 20 cm and should have a height of at least 50 cm.
- No glue, staples, nails or pins are allowed; however, you may use interlocking pieces.
- It must be freestanding (it may not be stuck to the table in any way).

Before testing, you will be required to explain the main aspects of your design to the client (your teacher) and describe what makes the model and the real building earthquake-proof.

on Resources

ProjectsPLUS Disaster-proof (proj-0108)

8.9 Review

Access your topic review eWorkbooks

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-4487	ewbk-4489	ewbk-4491

on Resources

8.9.1 Summary

The Earth's crust

- The Earth has three basic interior layers: crust, mantle and core.
- There are two types of crust: continental crust and oceanic crust. The oceanic crust is thinner and heavier.
- The mantle is mostly solid but soft rock.
- The core is made of iron and nickel, with a liquid outer core and solid inner core.
- The layers are not stationary, they move or flow due to convection currents.
- Alfred Wegener proposed that Pangaea was a supercontinent that broke apart by continental drift millions of years ago.
- Many continental shapes fit together like a jigsaw.
- Rock types and land-based fossils match across continents.

The theory of plate tectonics

- The theory of sea-floor spreading explains how ocean basins form and continents move apart.
- At a spreading centre, crust splits apart and melted mantle rises to fill the gap and forms new crust.
- Continental drift and sea-floor spreading theories evolved into the theory of plate tectonics.
- The Earth's surface is broken into fragments called tectonic plates that move relative to one another.
- Plates move under the influence of convection currents in the weaker mantle below.
- There are convergent, divergent and transform plate boundaries.
  - Convergent subduction is destructive, as old oceanic crust sinks back into the mantle, forming deep ocean trenches and volcanoes.
  - Convergent collision forms mountain ranges as continental crusts collide.
  - Divergent boundaries are constructive because new oceanic crust forms by volcanoes along the spreading centre of ocean ridges.
  - Transform boundaries are conservative as crust is neither created nor destroyed.
- All types of tectonic boundaries have earthquakes.
- The modern tectonic boundaries are identified and mapped by:
  - volcano and earthquake patterns
  - growing mountain ranges and ocean ridges
  - direct GPS measurements.
- Tectonic boundaries shift with time, constantly changing how the surface of the Earth appears.
- Australia is an old continent. It sits within the middle of the Indo-Australian plate and was once a part of a larger continent called Gondwana.

Rocks under pressure

- When huge tectonic forces are applied, rocks can bend into folds or break as faults.
- Folding occurs when there is a slow compression force, which shortens and thickens the crust.
- Folds can be anticlines (shaped like an 'A') and synclines (shaped like an upside-down 'A')
- Faults form when rocks in the upper crust (cool) are exposed to tectonic forces.
- There are three major fault types:
  - normal faults — the rock above the fault moves down, and is related to tension force like those at divergent boundaries

- reverse faults — rock above the fault moves up, related to compression force like those at convergent boundaries
- strike-slip faults — rocks move horizontally side by side, related to shearing force like those at transform boundaries.

- Australia has a long complex geologic history with many events of both folding and faulting.

Earthquakes

- Earthquakes are caused by breaking crust, releasing the built-up pressure.
- The vibrations (seismic waves) of an earthquake travel from the focus as both body and surface waves.
- P- and S-waves are body waves. P-waves are the fastest.
- Love and Rayleigh waves are slower surface waves.
- Seismic waves are recorded by seismometers that produce seismographs.
  - The size and spacing of the waves relate to the amount of energy released and the station's distance from the epicentre.
- Earthquake magnitude is measured on the Richter scale, which measures the amount of energy released by an earthquake.
- Large earthquakes are concentrated along the current plate boundaries.
  - Australia's earthquake potential is lower than those near plate boundaries.
- Tsunamis can form from underwater earthquakes that have lifted the sea bed and the water column above it.
- The extent of earthquake damage is not only related to the earthquake magnitude, but also the:
  - distance from the epicentre
  - population
  - building materials.

Volcanoes

- Volcanoes form when magma erupts onto the surface from over-pressured magma chambers underground.
- The erupted material can include red-hot lava, gas, rock, ash and volcanic bombs.
  - Runny lava produces a calmer eruption with long-distance lava flows.
  - Sticky lava produces an explosive eruption with steep-sided volcanoes.
- Volcanoes can be active, dormant, or extinct.
  - Most active volcanoes form along divergent and subduction boundaries.
  - Most volcanoes in Australia are classified as extinct.
- Volcanoes can also be related to hotspots, which occur in areas with anomalously hot mantle close to the surface.
- Oceanic spreading ridges contain chains of underwater active volcanoes with black smokers.

8.9.2 Key terms

abyssal plains relatively flat underwater deep ocean floor, around 4000 metres depth
active volcano a volcano that is erupting or has recently erupted
anticline a fold in a rock with the narrow point facing upwards
black smoker a geothermal vent on the sea floor that ejects superheated mineral rich water
body waves seismic waves that quickly travel through the interior of the Earth
collision when two continents crumple together to form a mountain range
compression squeezing force
conservative plate boundary where crust is neither created or destroyed
constructive plate boundary where new crust is formed
continental drift movement of the Earth's continents relative to each other over geologic time
convection currents the movement of particles in a liquid or gas resulting from a temperature or density difference
convergent boundary where two tectonic plates move towards each other
core hot centre of the Earth made of iron and nickel
crust hard and thin outer rock layer of the Earth

deep ocean trenches narrow and deep troughs in the ocean floor, generally greater than 5000 metres depth
divergent boundary where two tectonic plates move apart
dormant volcano a volcano that has erupted in the last 10 000 years but is not currently erupting. They are considered likely to erupt again.
earthquakes a sudden and violent shaking of the ground
epicentre the surface point directly above the earthquake focus
extinct volcano a volcano that *has not* erupted in the last 10 000 years. They are considered dead and not to erupt again.
fault a break in the crust where one side moves relative to the other
focus the location underground of the fault movement causing an earthquake
folding when rocks bend into anticlines or synclines
fossils the remains, impression or trace of a living organism preserved in rock
Gondwana the southern part of the broken-up supercontinent of Pangaea, which included the continents of Africa, South America, Antarctica and Australia; also known as Gondwanaland
horst a highland between two normal faults
hotspot a volcanic region directly above an area of anomalously hot mantle
inner core solid inner-most layer of the core under extreme pressure conditions, with an approximate 1200 km radius
Laurasia the northern part of the broken-up supercontinent of Pangaea, which included the continents of North America, Europe and Asia
lava extremely hot liquid or semi-liquid rock from the mantle, which has reached and flows or erupts on the Earth's surface
Love waves a surface seismic wave with a side-to-side motion
magma extremely hot liquid or semi-liquid rock within the mantle. When it erupts on the surface of the Earth it is called lava.
mantle solid but soft middle rock layer of the Earth
mountain range a group of high ground features, commonly the result of tectonic collision
normal fault a break where the rock above the fault moves 'down' due to tension
ocean ridges submarine mountains that tower 2000 metres above the abyssal plains
outer core liquid outer layer of the core, about 2300 km thick
P-waves or primary waves body seismic waves with a compressional (push-and-pull) motion; are the fastest and first to arrive
Pangaea a supercontinent that existed about 225 million years ago. All landmasses were joined together to form this supercontinent.
Panthalassa the vast ocean surrounding the supercontinent of Pangaea
plate tectonics a scientific theory that describes the relative movements and interaction of plates of the Earth's crust over the underlying mantle
radioactive atoms are unstable and will emit a particle to remove excess energy. These particles are capable of ionising other atoms upon collision, which can cause harm to living tissue.
Rayleigh waves a surface seismic wave that has a rolling motion
reverse fault a break where the rock above the fault moves 'up' due to compression
Richter scale a logarithmic scale that measures the amount of energy released during an earthquake, thus allowing one earthquake to easily be compared to another
rift valleys a sunken lowland between two normal faults; a graben
S-waves or secondary waves body seismic waves with a transverse (up-and-down) motion; are slower than P-waves and cannot travel through fluids
sea-floor spreading the formation of oceanic crust, which occurs by the rising and melting mantle at ocean ridges that push older crust away from the ridge
seismic waves waves released when rock breaks or is rapidly moved
seismograph an instrument used to detect and measure the intensity of an earthquake
seismologist a scientist who studies earthquakes to both understand how they work and how to better predict them
shearing a smearing force
strike-slip fault a break where the rocks on either side of the fault move horizontally due to shearing
subduction a convergent plate boundary where one plate moves under another
surface waves seismic waves that travel slower than body waves and only along the surface of the Earth; their energy is lost with depth and distance.

syncline a fold in a rock with the narrow point facing downwards
tension a stretching force
transform boundary where two tectonic plates slide past one another
tremors minor vibrations of the ground that are commonly not felt
tsunami a powerful ocean wave triggered by an undersea earth movement
volcanic bomb large rock fragment that falls from an eruption, formed as lava, is blown out of a volcano and is rapidly cooled in the air
volcanoes a landscape feature through which melted rock is erupted onto the Earth's surface

on Resources

eWorkbooks	Study checklist (ewbk-4493) Literacy builder (ewbk-4494) Crossword (ewbk-4496) Word search (ewbk-4498)
Practical investigation eLogbook	Topic 8 Practical investigation eLogbook (elog-0442)
Digital document	Key terms glossary (doc-34880)

8.9 Exercise

learnon

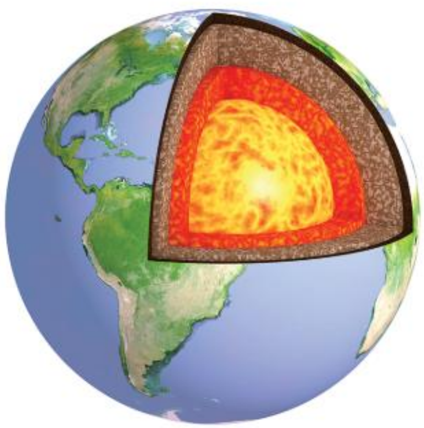
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 4, 5, 9, 11, 13, 15	Questions 3, 6, 10, 12, 16, 18, 19	Questions 7, 8, 14, 17, 20, 21, 22

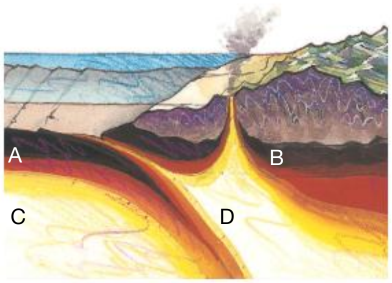
Remember and understand

1. Identify the layers of the Earth that have the following characteristics.
   a. Completely molten
   b. Solid but soft
   c. Solid and hard, and includes rock, soil and landforms
   d. Solid and mostly made of iron
   e. Lies above the surface
2. SIS Describe two pieces of evidence that were used to develop Wegener's theory of continental drift.
3. Explain how scientists know about what lies deep below the surface of the Earth without going there.
4. Where would you find the youngest oceanic crust according to the theory of sea-floor spreading?
5. How is an ocean ridge different from a subduction zone?
6. When oceanic crust pushes against continental crust, why does the oceanic crust slide underneath the continental crust?
7. What is the major difference between the continental drift theory and the theory of plate tectonics?
8. Describe the movements in the Earth's crust that cause the folding of rock and has shaped most of the Earth's mountains.
9. Explain how faults are created.

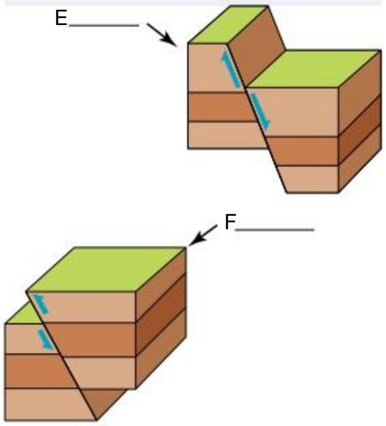


10. Examine the following diagrams and label the features A–H using the following words: anticline, continental crust, magma, normal fault, oceanic crust, reverse fault, upper mantle, syncline.

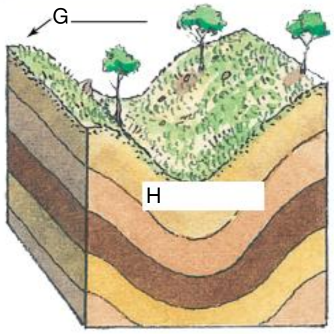
A subduction zone



Two types of faulting



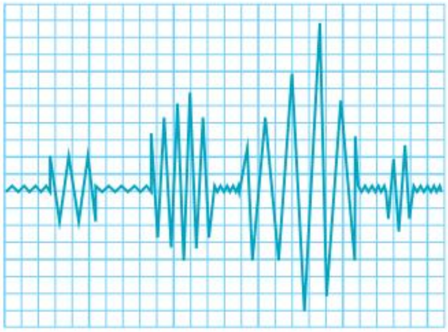
Folding upwards and downwards

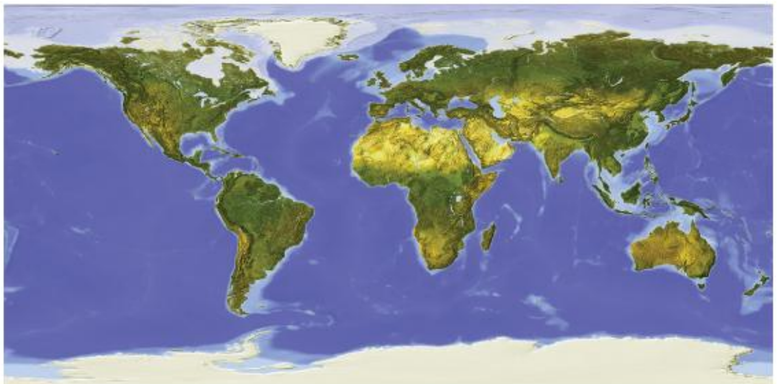


11. Distinguish between the epicentre of an earthquake and its focus.
12. What is a seismograph used to measure?
13. Name three gases that are released from a volcano.

Apply and analyse

14. The San Andreas Fault runs along much of coastal California, including the cities of Los Angeles and San Francisco, and is susceptible to earthquakes.
    a. Explain why the San Andreas Fault is called a slip fault.
    b. What causes major earthquakes along this fault?
15. Where on Earth is the Ring of Fire and why does it exist?





16. Suggest two reasons why an earthquake that registers 6.6 on the Richter scale can cause more deaths and devastation than an earthquake that registers 7.9 on the Richter scale.
17. How much energy is released by an earthquake that registers 6.0 on the Richter scale relative to one that registers 7.0?
18. Explain why Australia is less likely to experience volcanic activity and major earthquakes than New Zealand.
19. Tsunamis can form due to fault movements on the ocean floor, but there are other geologic events that can trigger a tsunami, such as a huge coastal or underwater landslip. How can a large landslip trigger a tsunami?
20. Before an explosive volcano erupts, its vents are blocked with thick, sticky lava.
    a. What change takes place to cause the volcano to erupt?
    b. How would runny lava change the eruption style?

Evaluate and create

21. According to the theory of plate tectonics, the Earth's crust is divided into a number of slowly moving plates.

a. What makes the plates move?

b. What can happen when two plates slide past each other?

c. How does the theory of plate tectonics explain the growth of the Himalayas? Your answer should include reference to convection, relevant plate boundaries, rock density and any limiting factors on the height of mountain chains.

22. **SIS** Observe the age of the volcanic shield volcanoes along the Great Dividing Range. Recall that the eastern margin of Australia has not been located near a plate boundary for the last 50 million years.

a. What is the pattern to the age relative to direction?
b. Based on your knowledge and observations, how would you explain the origin of the volcanoes?
c. Are there any inconsistencies to that pattern or other reasons as to why you may question the conclusion?

Fully worked solutions and sample responses are available in your digital formats.

on Resources

eWorkbook Reflection (ewbk-3038)

teachon

Test maker
Create customised assessments from our extensive range of questions, including teacher-quarantined questions. Access the assignments section in learnON to begin creating and assigning assessments to students.

RESOURCE SUMMARY

on Resources

Below is a full list of **rich resources** available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

8.1 Overview

eWorkbooks
- Topic 8 eWorkbook (ewbk-4473)
- Student learning matrix (ewbk-4472)
- Starter activity (ewbk-4475)

Practical investigation eLogbook
- Topic 8 Practical investigation eLogbook (elog-0442)

Video eLesson
- Volcanic eruption in Iceland 2010, Eyjafjallajökull (eles-2661)

8.2 The Earth's crust

eWorkbooks
- Labelling the layers of the Earth (ewbk-4477)
- Continental drift (ewbk-4479)

Practical investigation eLogbook
- Investigation 8.1: Continental drift (elog-0432)

Video eLessons
- Interior of the Earth (eles-4148)
- Drifting continents (eles-0129)

Interactivity
- Labelling the layers of the Earth (int-8163)

8.3 The theory of plate tectonics

eWorkbooks
- Plate tectonics (ewbk-4554)
- How does a hypothesis become a theory: Plate tectonics (ewbk-4556)

Video eLessons
- San Andreas Fault (eles-4149)
- Plate margins of the world (eles-4150)

Interactivity
- Does the Earth move? (int-0674)

8.4 Rocks under pressure

eWorkbook
- Folding and faulting (ewbk-4481)

Practical investigation eLogbooks
- Investigation 8.2: Modelling folds (elog-0434)
- Investigation 8.3: Modelling faults (elog-0436)

8.5 Earthquakes

eWorkbooks
- Earthquakes (ewbk-4483)
- Plotting earthquakes activity (ewbk-4485)

Practical investigation eLogbook
- Investigation 8.4: Making a seismograph (elog-0438)

Video eLesson
- Tsunami wave propagation during the 2004 Sumatra–Andaman tsunami (eles-4151)

8.6 Volcanoes

eWorkbooks
- Volcanic activity (ewbk-4558)
- Geological activity (ewbk-4560)

Video eLessons
- Volcanoes (eles-0130)
- Deep-sea mining (eles-1086)

8.8 Project — Disaster-proof

ProjectsPLUS
- Disaster-proof (proj-0108)

8.9 Review

eWorkbooks
- Topic review Level 1 (ewbk-4487)
- Topic review Level 2 (ewbk-4489)
- Topic review Level 3 (ewbk-4491)
- Study checklist (ewbk-4493)
- Literacy builder (ewbk-4494)
- Crossword (ewbk-4496)
- Word search (ewbk-4498)
- Reflection (ewbk-3038)

Practical investigation eLogbook
- Topic 8 Practical Investigation eLogbook (elog-0442)

Digital document
- Key terms glossary (doc-34880)

To access these online resources, log on to **www.jacplus.com.au**.

9 Energy transmission

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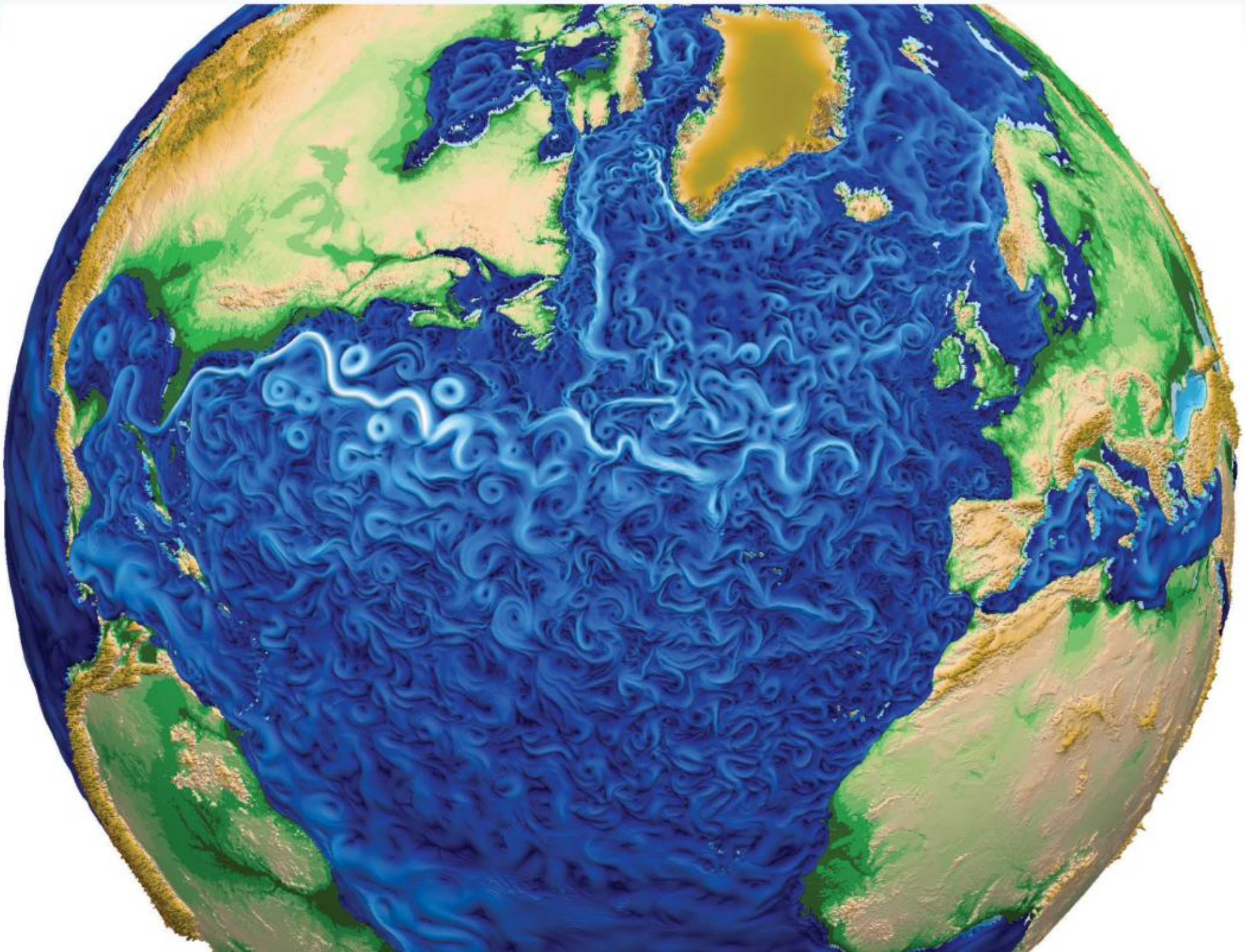


9.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

9.1.1 Introduction

If you take apart a smartphone you will find plastic, glass, computer chips, copper wire and so on. You won't find the 'energy' as it is not a 'thing'. Energy is a concept. Everything in the universe that has what we call energy is either moving or has been moved to a position where, with a nudge, movement can occur.

FIGURE 9.1 Your brain relies on energy transfers to communicate. The electrical impulses travel along the nerve fibres.

Think about the types of energy that you know. Electrical energy is moving electrons. Sound energy is moving particles in the air. Chemical energy is the energy stored in the bonds of chemical compounds. Kinetic energy is literally movement energy (the image that opens this topic shows the global ocean surface kinetic energy, 2015). If you put a ball on a shelf it has gravitational potential energy, which is, in essence, a way of storing energy. With a nudge, the ball can roll off the shelf and the stored energy is released and converted into kinetic energy as the ball falls.

We only really notice energy when it is transferred between objects or transformed into a different type of energy. When we touch fire, the heat energy in the flames (the quickly moving particles) is transferred to our skin (making our particles move more quickly). Strangely we cannot see a beam of light. It is only when the energy is converted to electrical impulses by our retina and optic nerve that we detect light. We detect sound waves when they transfer the kinetic energy of the air molecules to the moving parts in our ear.

Nothing in the universe can happen without the transfer or transformation of energy. In this topic, we consider how energy transfers in the environment are responsible for our habitable world. We then discover how we communicate by means of energy transfer and how we have developed technologies to extend our communication networks around the world and beyond.

9.1.2 Think about energy transmission

1. Why is it that of all the planets, only the Earth seems to support life?
2. Why do I feel so cold when I get out of the ocean even on a hot sunny day?
3. Why are the continents moving?
4. Why do some things give off light and others don't?
5. How does the sound get from one smartphone to another?
6. Will we ever be able to improve on our eyes and ears?
7. How can the blind see?
8. How will we be communicating in the future?

9.1.3 Science inquiry

Using energy to communicate

Since prehistoric times, we have had a need to communicate over a distance. Our early ancestors would make noise to warn of approaching predators. The communication range was short but it was enough to serve the purpose.

Once humans started to make settlements, we started to see the need for a form of communication that could take information a greater distance. Smoke signals, large bonfires and drums were used to send simple messages. Anything more complex required the delivery of hand-written letters, which only happened after the invention of writing around 6000 years ago. Shortly after writing was invented came messenger services. Important messages would be given to runners who would hand-deliver news. Due to the likelihood of these messages being intercepted by an enemy, codes and encryption were also invented soon after.

FIGURE 9.2 Global communication began with ships

With the invention of the ship for ocean navigation and the exploration of the globe, communication eventually became a global issue. In March 1791, Captain Arthur Phillip, Governor of New South Wales, wrote a letter to his employer, King George III in London, asking for some time off work. The only way to get the letter to London was by sailing ship. The letter took 8 months to get to King George III, and his reply took a further 8 months to reach Sydney. A faster technology was clearly needed if we were to regularly communicate around the planet.

Although the transmission of matter is a lot faster today, a letter sent from Sydney to London via airmail would still take about 5 days to arrive and at least another 5 days for the reply to be received in Sydney. A much faster method of communication is via telephone or email, which only take seconds to arrive. There is no longer any need for matter, such as letters, to be transported. The message sent between Sydney and London via the transmission of energy can be sent at the speed of light — 300 000 kilometres per second. Over long distances, there are many advantages of energy transmission without the transmission of matter. Answer the following questions about how we use energy to communicate.

1. What has changed since 1791 to reduce the communication time from Sydney to London and back from 16 months to 10 days?
2. What are all of the options now available for sending a message from Sydney to London? Which options do not require the movement of matter from Sydney to London and back? How fast is this communication?
3. If matter does not move from one place to another when a message is sent over a long distance, what does move?

Even over a short distance the transmission of energy is faster than the transmission of matter. Imagine that you want to warn a couple of friends that they are about to be hit by an out-of-control skateboarder. Your options for saving them include:

A. yelling at them to get out of the way
B. yelling and pointing at the skateboarder
C. waving your arms in the air and pointing
D. holding up a sign that says 'Watch out!'
E. running across the road to push them out of the way.

4. Which of the options **A**–**E** involves:
   a. the transmission of matter
   b. the transmission of energy
   c. the transmission of both matter and energy?
5. In your opinion, which of the options **A**–**E** is the:
   a. fastest
   b. slowest
   c. least safe?

6. Write down as much as you know about the following types of invisible waves.
   a. Sound
   b. Ultrasound
   c. Visible light
   d. Microwaves
   e. Infra-red
   f. Radio waves

on Resources

eWorkbooks Topic 9 eWorkbook (ewbk-3814)
Student learning matrix (ewbk-3155)
Starter activity (ewbk-3816)

Practical investigation eLogbook Topic 9 Practical investigation eLogbook (elog-0272)

learnon Access and answer an online Pre-test and receive **immediate corrective feedback** and **fully worked solutions** for all questions.

9.2 Heat transfer

LEARNING INTENTION

At the end of this subtopic you will be able to distinguish between heat and temperature, be able to define absolute zero and describe the key mechanisms of energy transfer.

9.2.1 Heat and temperature

The amount of heat energy (or thermal energy) that an object has is due to the total **kinetic energy** of every particle in the object. You may have seen in science fiction movies that space is cold. This is true, it is approximately –270 °C. At this temperature the particles have almost stopped moving. Just 3 degrees colder and the particles would stop completely. This is what we call **absolute zero**. You cannot get colder than this.

kinetic energy energy due to the motion of an object

absolute zero the lowest temperature that is theoretically possible, at which the movement of particles stops. It is zero on the Kelvin scale, equivalent to –273.15 °C.

Clearly there is a link between the idea of heat and temperature but they are not the same thing. A typical sparkler will throw off sparks with a temperature of over 1000 °C, but as they have a small mass their heat energy is quite low, making them practically harmless. The sparks are at a temperature that makes them glow with visible light. Each spark is safe, but the larger mass of the sparkler makes it dangerous to touch.

FIGURE 9.3 Liquid nitrogen is comparatively warm compared to space at only –196 °C. Objects placed in liquid nitrogen will become brittle and may shatter as their particles slow down causing the object to contract.

However, we know that if you spill boiling water on yourself it will burn you. The water at 100 °C is much cooler than the spark, but as there are so many more particles involved there will be a much greater heat energy. Temperature is only a measure of the average kinetic energy of the particles, not the total energy in the object.

FIGURE 9.4 The tiny sparks have a very high temperature, but their small mass means their heat energy is low.

FIGURE 9.5 Boiling water has a temperature of only 100 °C but there are many particles of boiling water.

Temperature is a measure of the average kinetic energy of the particles, not the total energy in the object. This is vital to understand in the context of such issues as climate change. A rise in temperature of one degree doesn't sound like a lot, but when you think about all of the particles in the atmosphere you realise that this means a huge amount of extra energy will be in the atmosphere.

DISCUSSION

If you have an object at 0 °C and you double the energy content, do you just double the temperature?

9.2.2 Heat flow

When an object is warmer than its surroundings, heat energy will flow out of it in one or more ways. These are **conduction**, **convection**, **radiation** and **evaporation**.

Conduction

Conduction occurs when a particle passes kinetic energy on to another particle. This can happen during collisions. For example, when an oxygen molecule in the air hits your arm, it will leave more quickly than it arrived as the faster particles in your arm transfer energy to the oxygen molecule.

More commonly, we think of conduction as heat transfer in a solid. Most solids are better conductors than liquids and gases because their particles are more tightly bound and closer together than those of liquids and gases. Conduction is a slow way to transfer energy in liquids and gases.

conduction the transfer of heat through collisions between particles

convection the transfer of heat through the flow of particles

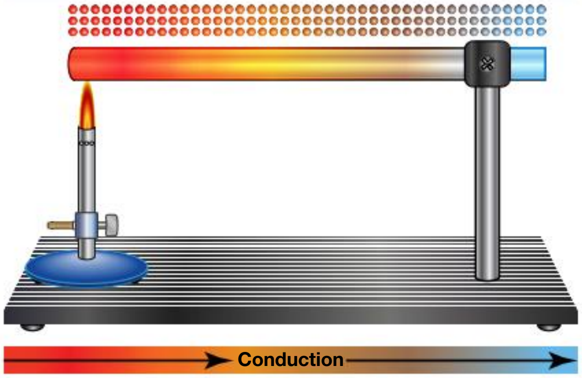
radiation a method of heat transfer that does not require particles to transfer heat from one place to another

evaporation the change of a liquid into a vapour at a temperature below the boiling point and at the surface of a liquid. Molecules with the highest kinetic energy escape, lowering the temperature of the liquid.

The particles in a solid have bonds between them. These help to transfer the energy from the hot region to the cold region. Imagine one end of a metal bar is heated by contact with the hot gases from a Bunsen burner, let's consider what happens next:

- The particles at the warm end gain kinetic energy.
- This means they vibrate more.
- As the faster particles are connected to other particles by bonds, the neighbouring particles are pulled around more.
- This means that *energy has been transferred*.
- This transfer of energy continues down the bar towards the colder end.
- This will only stop when the bar is the same temperature at all points and the energy is shared evenly between the particles.

FIGURE 9.6 In a solid, heat energy will be transferred from a hot region to a cold region by conduction.



Metals are the best conductors of heat. The electrons of metals are freer to move than those of other solids and are therefore able to transfer their kinetic energy more readily to neighbouring electrons and atoms. We use metals to efficiently transfer heat in many situations. A common use is in computers and phones where metal **heat sinks** prevent the processors from overheating.

Materials that are poor conductors are called **insulators**. Materials such as polystyrene, foam, wool and fibreglass batts are effective insulators because they contain pockets of still air. Air is a very poor conductor of heat.

heat sink device that transfers the heat generated by an electronic or a mechanical component to a coolant, often the air or a liquid, where it can be taken away from the component

insulator material that has a very high resistance, allowing very little current to flow through it

SCIENCE INQUIRY SKILLS: Choosing a graph

When drawing graphs you need to decide on the type of graph to be used. Different types of data are better suited to different types of graphs.

Quantitative data: numerical data that examines the quantity of something (for example, length or time).

Qualitative data: categorical data that examines the quality of something (for example, colour or gender) rather than numerical values.

Line graphs or scatterplots: use if both the independent and dependent variables are quantitative.

Bar graphs: use when one piece of data is qualitative and the other is quantitative.

Histograms: use when intervals and frequency are being explored.

Remember when drawing a graph to:

- include a title. This should link the dependent and independent variables that are shown in the graph.
- assign axes correctly. In most graph types (excluding pie graphs), the independent variables should be on the horizantal (*x*) axis, and the dependent variable is on the vertical (*y*) axis.
- rule axes and label each clearly. Those displaying numerical variables should have a clearly marked scale and units.
- make sure your scale is suitable and the numbers are evenly distributed.
- use a line (or curve) of best fit as required. This is a smooth curve or line that passes as close as possible to all the plotted points.
- include the origin, the zero values for the variables, on both axes. You may need to use an axis break symbol if all the values you are plotting are clusttered around high values.

CASE STUDY: Baking with ice-cream!

Imagine putting a scoop of ice-cream into a 230 °C oven for three minutes. That's exactly what you do when you make Bombe Alaska, a dessert with a solid ice-cream centre on a sponge cake, covered with meringue. Bombe Alaska — ice-cream and all — is baked in a preheated 230 °C oven for three minutes. Yet the ice-cream doesn't melt! The secret to this is the insulating properties of the sponge and meringue. The bombe pictured here has strawberry (pink) and orange ice-cream on top of the sponge cake. The white meringue has been cooked and has been changed to a brown colour by the heat of the oven. The poor conduction properties of the meringue have not been able to transfer heat to the ice-cream.

elog-0274

INVESTIGATION 9.1

Heat conduction in solids

Aim

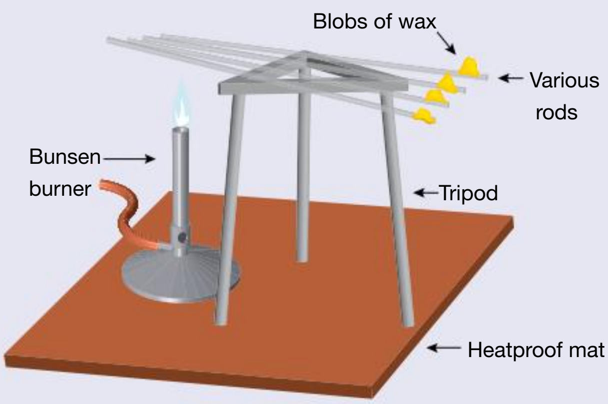
To compare the conduction of heat through different metals

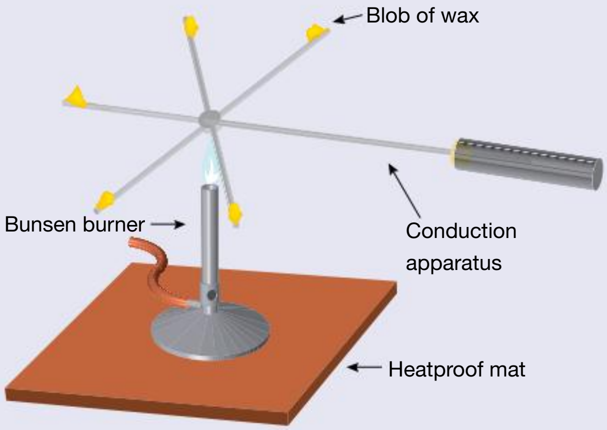
Materials

- set of 3 or 4 metal rods (different metals but identical in size) or a heat conduction apparatus
- wax candle
- Bunsen burner and heatproof mat
- matches
- tripod
- ruler
- stopwatch

Method

1. Set up the tripod and rods or heat conduction apparatus as shown.
2. Light the candle and melt a blob of wax onto one end of each rod. Ensure that each wax blob is the same distance from the end that will be heated by the Bunsen burner flame.
3. Use the blue flame of the Bunsen burner to heat the end of each rod. Start the stopwatch at the instant that heating begins.
4. Record the time taken for each blob to produce its first droplet of wax.
5. Repeat steps 1–4 for each different metal rod.





Results

1. Record your data in a table.
2. Present your data as a bar or column graph. Consider why these are the best choices to plot your data.

Discussion

1. According to your data, which of the metals is the best conductor of heat?
2. According to your data, which of the metals is the poorest conductor of heat?
3. Identify the independent and dependant variables in your investigation.
4. Compare your data with that of others in your class. Comment on the consistency of the conclusions within your class. If there was inconsistency, suggest one or more reasons for it and suggestions to improve the experiment.

Conclusion

Write a conclusion to your investigation, remembering to refer back to the aim.

Convection

Unlike the particles that make up solids, those of liquids and gases are able to move around. In liquids and gases, heat can be transferred from one region to another by the actual movement of particles. This type of heat transfer is called convection.

FIGURE 9.7 Heat transfer in a solid, a liquid and a gas

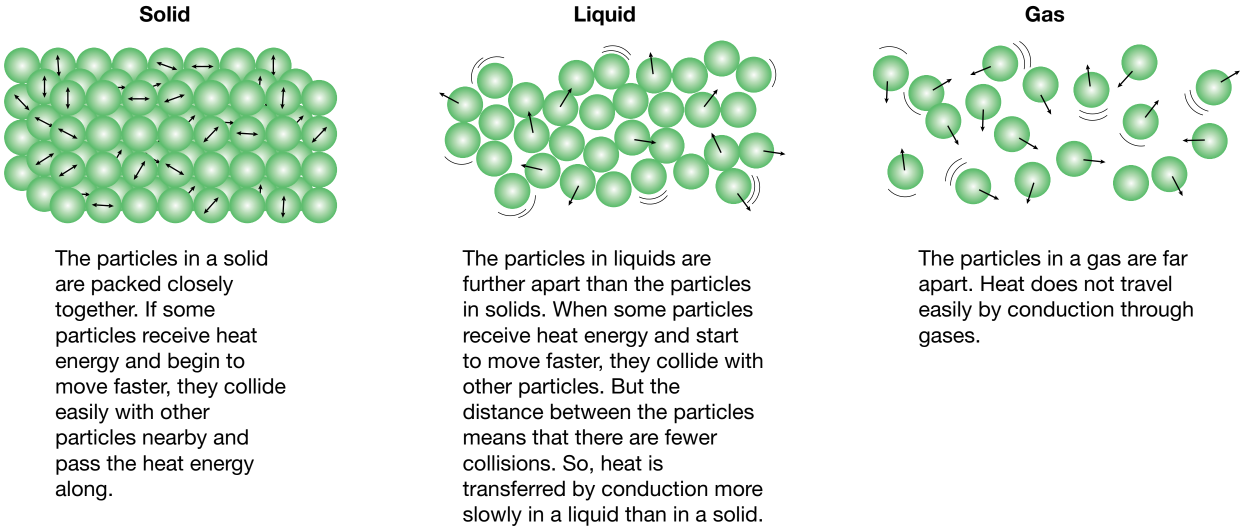


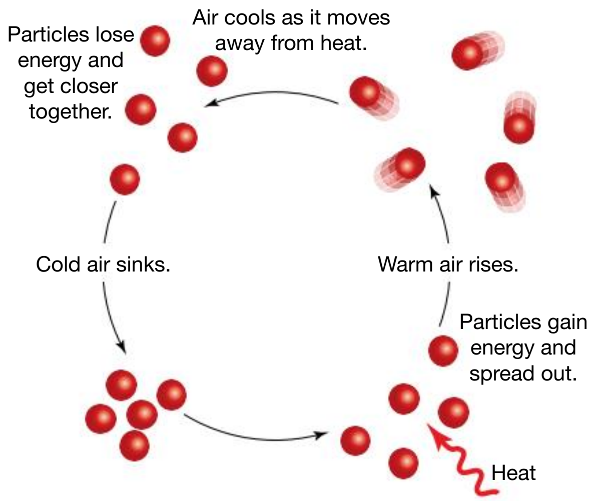
Figure 9.8 shows how convection takes place in air:

- Particles are heated. They gain *kinetic energy* and move around more.
- The heated air is now *less dense*.
- Less dense things float on more dense things and so the hot air rises.
- This also means that cold air must sink down to take the place of the hot air.
- As the faster moving particles rise, they collide with other particles sharing out the energy.
- The once hot air is now cooler and will now take up less space, become denser and sink.
- The process repeats until all of the air is the same temperature.
- We call this cycle of heat, rise, cool, fall, repeat a **convection current**.

convection current the movement of particles in a liquid or gas resulting from a temperature of density difference

Home heating systems create convection currents that move warm air around. When ducted heating vents are in the floor, warm air rises and circulates around the room until it cools and sinks, being replaced with more warm air. Powerful fans are not necessary. Gas wall heaters have fans to push warm air across the room near floor level so that it heats the entire room. Ducted heating vents in the ceiling require powerful fans to push the warm air downwards so that it can circulate more efficiently.

FIGURE 9.8 Modelling heat transfer in air



Hot summer days by the sea

Coastal areas usually experience less extreme maximum temperatures on hot summer days as a result of **sea breezes**. This occurs by the following process:

- During hot summer days, radiant energy from the sun heats the land and the sea.
- As a result of the different properties of the land and water, after a few hours the land has a higher temperature than the sea.
- The hot air over the land expands, becoming less dense than the cooler, denser air over the sea.
- The air over the land becomes hot as a result of conduction.
- The cooler air over the sea rushes in towards the land, replacing the rising warm air, causing a sea breeze. At night, if the sea temperature is higher than the land temperature, the convection currents move in the opposite direction, creating a flow of air towards the sea.

FIGURE 9.9 Convection currents circulate warm air pushed out by heaters around the room.

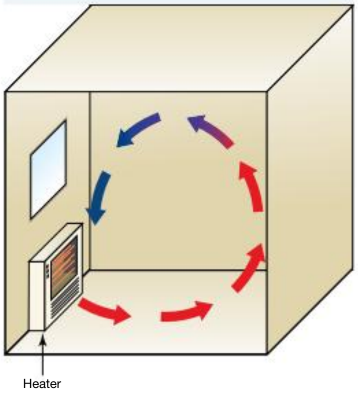
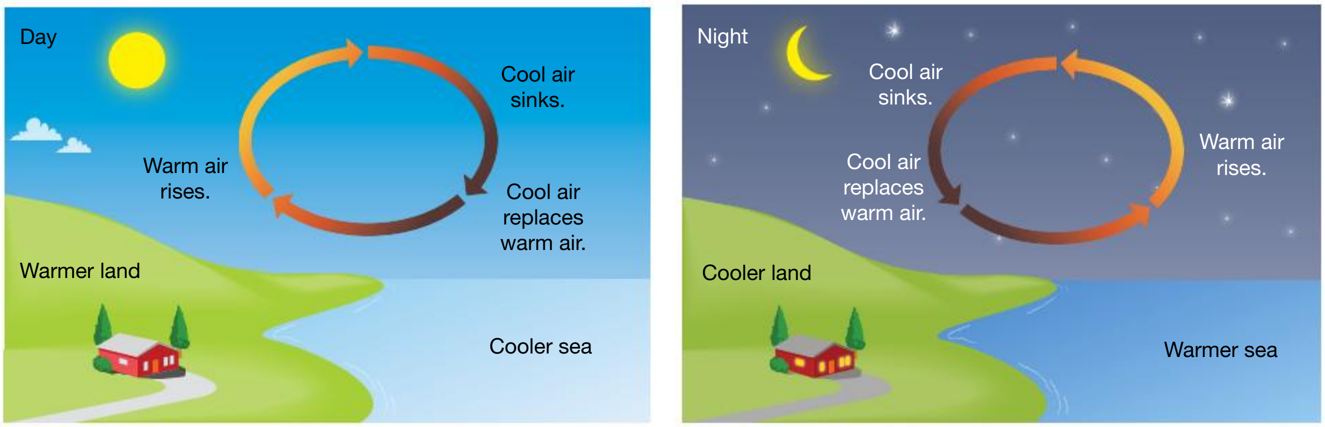


FIGURE 9.10 A sea breeze is caused by convection currents in the air during warm summer days. At night the convection currents are reversed.



sea breeze the breeze that occurs when differences in air pressure cause air particles to flow from the ocean towards the land

on Resources

eWorkbook Conduction and convection (ewbk-3839)

Radiation

Heat can be transferred without the presence of any particles at all, as electromagnetic radiation or light. Heat transferred in this way is called **radiant heat**. As you will see later in this topic, not all forms of light are visible to our eyes. One type of light that you can't see but can feel is *infra-red light*. If you hold your hand over a hot object you can feel the heat even if it is not glowing with visible light.

Heat from the Sun reaches the Earth by radiation, most of it in the form of infra-red radiation. There are not enough particles between the Sun and Earth for heat transfer by either conduction or convection.

There are three things that can happen when electromagnetic radiation meets an object. As an analogy, let us imagine a bullet fired at a target. What could happen?

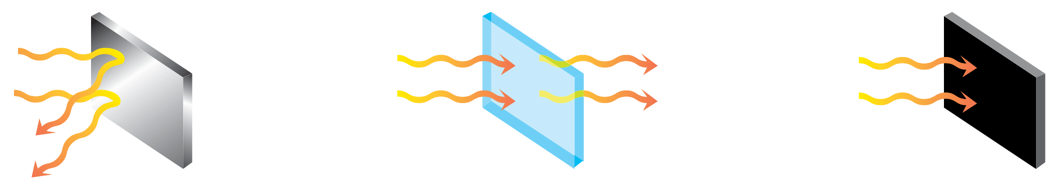
- If the energy of the bullet is too little it may just bounce off the target: it would be reflected.
- If the energy is high enough it may pass through the target: it would be **transmitted**.
- If the energy is within a narrow range it may stick in the target without passing through: it would be **absorbed**.

In a similar way, when the infra-red light waves that we call radiant heat meet an object, they can be reflected, transmitted or absorbed. How much energy is reflected, transmitted or absorbed depends on the properties, including colour, of the surface.

int-3400

FIGURE 9.11 Heat may be reflected, transmitted of absorbed.

Reflected radiant heat | **Transmitted radiant heat** | **Absorbed radiant heat**



Shiny or light-coloured surfaces tend to reflect light and radiant heat away. The temperature of these objects does not change quickly when heat reaches them by radiation.

Clear objects, like glass, allow light and radiant heat to pass through them. The temperature of these objects does not increase quickly when heat reaches them by radiation.

Dark-coloured objects tend to absorb light and radiant heat. Their temperatures increase quickly when heat reaches them by radiation.

radiant heat heat that is transferred from one place to another by radiation

transmitted light is passed on from one place to another through space or a non-opaque substance

absorbed energy hitting an object is transferred to it. This will cause the atoms in the object to vibrate more and the temperature will rise.

elog-0276

INVESTIGATION 9.2

Radiating and absorbing radiant heat

Aim

To compare the radiation and absorption of heat through black surfaces and shiny surfaces

Materials

- heater or microscope lamp
- 2 identical shiny, empty, soft-drink cans
- matt black paint and paintbrush
- 2 thermometers or data logger and 2 temperature sensors

Method

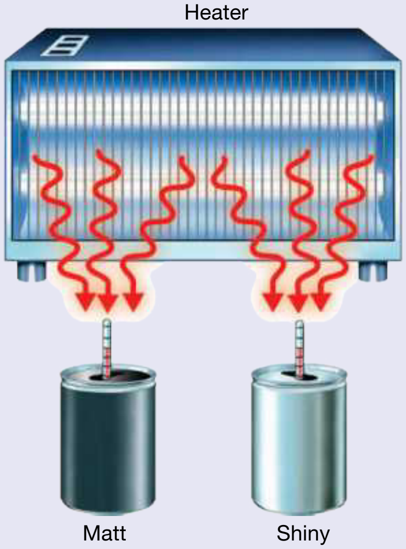
1. Paint one of the cans matt black and leave the other as it is.
2. Construct a table or spreadsheet headed 'Part A: Radiating heat' in which to record the temperature every 2 minutes for up to 14 minutes.
3. Make a prediction about your results and write down a hypothesis.

Part A: Radiating heat

4. Pour equal amounts of hot water into each can.
5. Place a thermometer or temperature probe into each can. Measure the initial temperature of the hot water and again every two minutes.
6. Empty the cans and pour equal amounts of cold tap water into each can.

Part B: Absorbing radiating heat

7. Construct a table or spreadsheet headed 'Part B: Absorbing radiant heat' in which to record the temperature every 2 minutes for up to 14 minutes.
8. Place a thermometer or temperature probe into each can. Measure the initial temperature of the water.
9. Place the two cans at equal distances from a heater or microscope lamp.
10. Measure and record your data into the table or spreadsheet every 2 minutes.



Results

1. Before you undertake the experiment, make a prediction about your results for Part A and Part B and write down a hypothesis for each part.
2. Enter your data into a table or spreadsheet.
3. Plot line graphs that show how the temperature changed over 14 minutes during the cooling and heating of the cans. You may wish to plot both graphs on the same set of axes.

Discussion

Part A: Radiating heat

1. Which can radiated heat more quickly?
2. Did your data support your hypothesis?

Part B: Absorbing radiating heat

3. Which can absorbed heat more quickly?
4. Did your data support your hypothesis?
5. Why was it important to use cans that were identical in size and shape?
6. What other variables had to be controlled during this experiment? Identify the independent, dependent and control variables.

Conclusion

Write a conclusion to your investigation, remembering to refer back to the aim.

Evaporation

Evaporation happens when a liquid changes state to become a gas. Evaporation occurs at the surface of the liquid. Let's consider the particles that are evaporating:

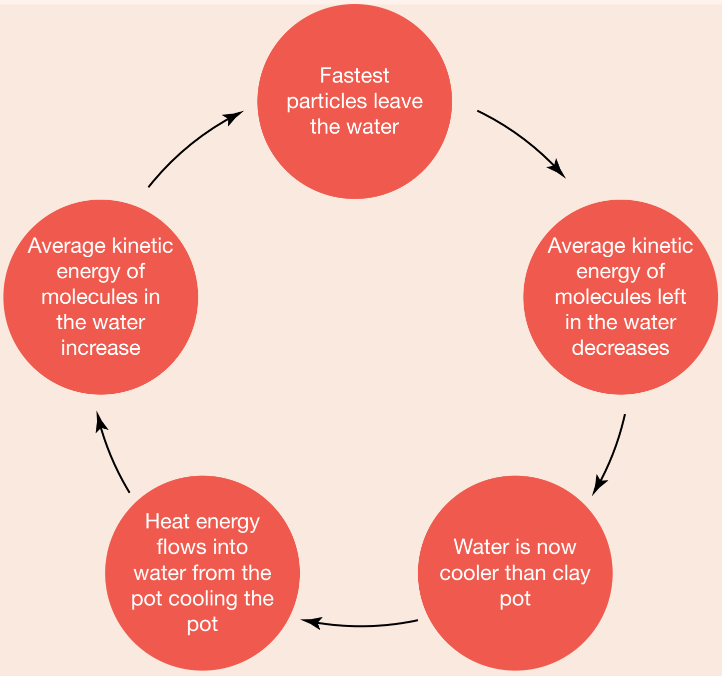
- All particles are moving at random, but they are moving at a range of speeds.
- Only the fastest particles with the highest energy can escape the liquid state and become a gas.
- When the fastest particles leave, this reduces the average kinetic energy of the droplet so it cools down.
- Blowing across the liquid helps more particles to escape, and cooling will occur more quickly. This is why a breeze, or a fan, helps you cool down.

SCIENCE AS A HUMAN ENDEAVOUR: Clay pot coolers

For thousands of years, the principle of evaporation to cool things down has been used by people to keep perishable food cool and preserved. Clay pot coolers existed at least as far back as ancient Egypt. A pot containing food would be placed inside another pot with wet sand between them. As the water in the sand evaporated, it took heat energy away from the pot containing food. Rough pots work best as they have more surface area so more evaporation can occur.

FIGURE 9.12 Clay pot coolers extend the life of perishable food.

FIGURE 9.13 Cooling cycle for evaporation of water in a clay pot cooler



on Resources

assess on Additional automatically marked question sets

9.2 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Which form of energy do particles transfer to each other as heat flows through a conductor?
2. Fill in the blanks to complete the sentence.
   Solids such as polystyrene foam and wool are ______ conductors of heat because they have many small ______ filled with ______, which is an ______ because the molecules are so ______apart that they hardly collide and so transfer very little ______ energy.
3. Explain why air near a wall furnace rises when it gets warmer. Name the process and explain how the process can keep going.
4. MC Which form of electromagnetic radiation from the sun is responsible for most of the radiant heat reaching the Earth?
   A. X-rays
   B. Ultra-violet
   C. Infra-red
   D. Visible light
5. The three things that can happen to radiant heat when it arrives at any surface are that it can be **absorbed**, **reflected** or **transmitted**. For each of the following materials state which of the three behaviours are **most** likely.
   a. a mirror
   b. a black car seat
   c. a window

Apply and analyse

6. Explain, with the aid of a diagram, how a coastal sea breeze results from convection currents.
7. Explain whether a puddle is likely to dry out faster or slower if you spread it out more.
8. Suggest why metal saucepans usually have plastic or wooden handles.
9. Fill in the blanks: Many sportspeople wear ______coloured clothing when competing on hot summer days because this colour is a poor _______of radiant heat from the Sun.

Evaluate and create

10. SIS Design a fair experiment to test the relationship between hair-dryer temperature and time taken to dry your hair. Think of three experimental variables that must be controlled. Make a prediction about what the outcome would be.
11. SIS In an experiment to determine hair-drying time at different hair-dryer temperatures, the following data were produced.

TABLE Hair dryer temperature and time to dry hair

Hair-dryer temperature (°C)	Time to dry (seconds)
60	65
55	80
50	95
45	115
40	135
35	150

a. Produce a line graph of the data. State what the trend shows and predict the amount of time to dry the hair using a hair dryer that produces 65 °C air.
b. By considering your graph, use your scientific knowledge to explain why a 60 °C hair dryer works more quickly, and work out whether it is worth paying three times as much for this hair dryer than one that makes 40 °C air.

12. To which form of heat transfer do the following statements apply?
 a. Energy is transferred at the speed of light.
 b. Particles move from one place to another.
 c. No particles are required for energy transfer.
 d. This form of heat transfer is best explained by a wave model.
 e. Free electrons in metals improve the efficiency of this type of heat transfer.
 f. The fastest particles leave the substance and cool it in this type of energy transfer.

Fully worked solutions and sample responses are available in your digital formats.

9.3 Controlling heat transfer

LEARNING INTENTION

At the end of this subtopic you will be able to explain why controlling heat flow is important. You should be able to identify when heat flow will occur, by what mechanism and how to reduce or enhance it.

SCIENCE AS A HUMAN ENDEAVOUR: Controlling heat transfer

There are many situations where we need to control the amount of heat energy in an environment or in an object. If a room is cold, we may rely on convection or radiation to heat it. Putting heat INTO an environment isn't too hard. Taking heat OUT of an object to prevent overheating can be harder. Examples already given are heat sinks for cooling processors and clay pot cooling for keeping food fresh. Similarly, we may want to reduce heat loss from an object by insulating it with materials that prevent convection, conduction, radiation and evaporation.

In all of the situations in this subtopic, our lives have been made better, or more thrilling, by clever control of heat flow.

Firewalking

Many cultures will perform firewalking rituals. In these, people walk barefoot across hot fire embers (between 500 °C and 1000 °C). It is possible to walk briskly across the embers without harm to the feet, but if the fire has not been prepared properly, or if the walker loses their nerve, serious injury can occur. By considering what we know about heat transfer, can we suggest how this may be possible?

There are a number of factors at play:
- The coals are poor conductors so heat flow is relatively slow.
- The water in the sweat on their feet can absorb and evaporate away large amounts of energy.
- If you walk briskly you will not remain in contact with the heat for very long.

FIGURE 9.14 People firewalk across a holy bonfire at Tai-sia-hood-jow Trang Shrine

The modern home

Many older homes today were built in a time when energy was inexpensive and there was little thought of the damaging effects of carbon dioxide on our planet. These homes get hot in the summer and require energy-hungry cooling. They also get cold in the winter and require a lot of heating to replace heat loss through the walls, windows and ceiling. Modern homes are now more commonly built with the idea of controlling heat transfer in mind.

- Foam insulation (full of tiny air pockets) in the walls prevents heat loss by conduction.
- Double glazing in the windows where the inner and outer glass panes are separated by an air gap also prevent heat loss by conduction.
- Roof insulation of fibre-glass wool containing small air pockets prevent convection and conduction of heat.
- Evaporative cooling whereby a small amount of water is used to remove heat from the house by evaporation. This is much less expensive and polluting than more energy-hungry solutions like refrigerated air conditioning.

FIGURE 9.15 A worker spraying closed cell spray foam insulation between the timbers in a wall

Body temperature

A healthy human body has a **core body temperature** of about 37 °C. With the right clothing and shelter, the inner parts of your body remain at this temperature almost anywhere on Earth.

The energy needed to keep your core body temperature at 37 °C is converted from the chemical energy in food. However, when you exercise, your body needs more oxygen and more energy. This extra energy is converted from food more quickly than when you are resting. Much of the converted energy causes an increase in body temperature.

In cool weather, your body is able to cool itself by transferring the extra heat into the surrounding air. However, in warm weather, it is much more difficult for your body to cool down.

Your body can protect itself from getting too hot by transferring heat from your skin to the cooler air surrounding it. This happens in four different ways.

- Cooling by radiation: If the surrounding air is cooler than your skin, most of the heat is transferred by radiation. The bigger the difference between your skin temperature and the air temperature, the more heat is radiated. When your core body temperature rises, the blood vessels beneath your skin get larger. This brings hot blood closer to your skin so that more heat is radiated away.
- Cooling by convection: Heat rises from the warm layer of air just above your skin into cooler air.
- Cooling by conduction: A small amount of heat is lost by conduction from your skin to the air. The amount is small because there is a thin layer of still air above your skin. There is also an insulating layer of fat beneath your skin.
- Cooling by evaporation: When your core body temperature increases, sweat glands under your skin produce **perspiration**. The energy needed to change the liquid water (perspiration) into water vapour comes from your skin. In other words, heat is transferred from your skin to the water on your skin.

When the air temperature is higher than your skin temperature, evaporation of water is the only way your body can reduce its temperature naturally. If you wear tight-fitting or too much clothing in hot weather or while exercising, you limit the evaporation of water from your skin. Your body is in danger of overheating.

core body temperature the operating temperature of an organism, especially near the centre of the body

perspiration the salty fluid produced by sweat glands under the skin

on Resources

Interactivity Insulating your body (int-3402)

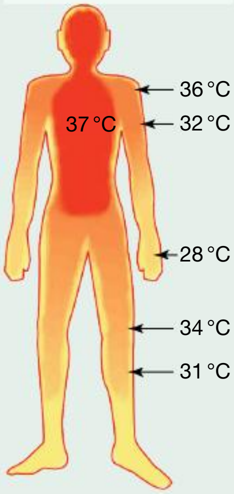
EXTENSION: Body temperature in cold weather

In cold weather, only the core of your body remains at 37 °C. The core is where all of your most important organs are. The other parts of your body can be quite a lot cooler. In warm weather, the temperature of your body is more even. Most of it remains within one degree of 37 °C. However, if the core body temperature drops, it can also have serious consequences.

- **Hypothermia** occurs if the core body temperature drops below 35 °C. The body starts shivering, and breathing may be slow and shallow. If the person is not warmed up, their speech will slur. If left untreated, hypothermia can lead to complete failure of the heart and respiratory system.

Hypothermia occurs when a person is not dressed sufficiently for cold weather or is immersed in cold water.

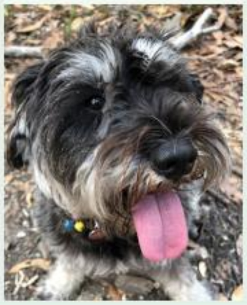
FIGURE 9.16 Variation in body temperature



EXTENSION: How do dogs control body temperature?

Dogs have sweat glands only in their feet. These glands don't do much to help dogs reduce their body temperature. A dog controls its body temperature by sticking out its tongue and panting. Air passing over its tongue and mouth evaporates its saliva. When a dog pants, some water evaporates from its throat and lungs. The energy transferred from the dog to cause all this evaporation keeps it cool. When humans evolved finer hairs on our body, exposing our skin, we also evolved sweat glands over our whole skin surface. This meant that we could keep running for longer than nearly every other animal in hot weather conditions. This allowed early humans to chase down much faster animals who would drop from heat exhaustion long before the humans. Who would have thought that sweat is our superpower!

FIGURE 9.17 Dogs control their body temperature by panting



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hypothermia a dangerous medical condition that occurs when the body temperature is below its normal range

9.3 Exercise

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Select your pathway

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

Remember and understand

1. MC What is the core body temperature of a healthy human body?
   A. 35 °C B. 36 °C C. 37 °C D. 38 °C
2. Fill in the blanks to complete the sentences.
   When you perspire, your sweat changes state from a __________ to a __________. This __________ the droplet of sweat so __________ energy transfers from your __________ to the sweat, and so __________ your body temperature.
3. Sometimes our bodies cannot cool efficiently. Match the situations below to the type of energy loss transfer that is prevented.

Situation	Type of energy loss
a. Thick clothing	A. Evaporation
b. Air around you is above body temperature	B. Convection
c. You are dehydrated	C. Radiation

Apply and analyse

4. Why does the skin become red during vigorous exercise? How does it achieve this?
5. Antiperspirants are used to reduce perspiration and body odour. Sketch a PMI chart about antiperspirants.
6. Imagine that you are the coach of a long-distance runner competing in a 21-kilometre race on a warm day. Make a list of 'dos and don'ts' for the runner so that dehydration, heat exhaustion and heatstroke are avoided. Present your list as a poster or PowerPoint presentation.

Evaluate and create

7. SIS A roofer wants to evaluate the amount of radiant heat escaping through a number of tiles of different colours. Design an experiment that could be conducted to do this, identifying the independent, dependent and controlled variables.
8. SIS The results of an experiment on different-coloured tiles showed the following energy transmitted over the course of the experiment. Chart these results. Explain the relationship between the variables and determine, with a reason, the best tile to use.

TABLE Coloured tiles and radiant heat transmitted

Colour	Radiant energy transmitted (J)
Black	100
Blue	85
Green	70
Yellow	35
Red	65
Brown	75

9. **SIS** Design an experiment to compare the effectiveness of the insulation due to conduction only in an insulated flask, compared to a design that allowed conduction to occur. Explain how your design works. State variables that you will measure and control. Assume you have multiple vacuum flasks all of the same design.

Fully worked solutions and sample responses are available in your digital formats.

9.4 Heat transfer and the planet

LEARNING INTENTION

At the end of this subtopic you will be able to explain how convection leads to the dynamic movements of the surface of the Earth and provides a protective shield for the Earth. You will be able to describe weather in terms of energy differences leading to convection and the processes leading to climate change.

9.4.1 The Earth's core keeps you alive

DISCUSSION

Approximately 97 per cent of climate scientists have concluded that climate change is man-made. Does this mean that scientists are not 100 per cent sure? Can a scientist ever be 100 per cent sure?

Understanding the way that heat is transferred to and around our planet is going to be vital for the survival of our species. Changes to the atmosphere caused by human activity have changed its insulation properties. This is resulting in a warming world, which if left unchecked could cause severe problems for our society.

As we explored in topic 8, magma heated by the Earth's **radioactive** core drives huge convection currents in the **mantle**. These currents in turn push the crust, slowly moving the continents in the process known as **plate tectonics**.

These convection currents in the mantle create large electrical currents in the Earth. As we will cover in topic 10, electrical currents produce magnetic fields. This means that Earth has a large magnetic field around it that protects us from the charged particles that constantly bombard the planet due to solar activity. Without the magnetic field, our atmosphere would long ago have been stripped away. This means that we owe our existence to the vast convection cells beneath our feet!

9.4.2 Convection and climate

The energy from the Sun does not spread evenly over the surface of the planet. At the equator sunlight strikes the surface of the Earth directly, but at the poles the light comes in at a shallower angle, spreading the energy over a larger land area. This means that the equator receives much more energy per square meter of land than the poles do. However, the rule still holds that heat energy will flow from a hot region to a cold region. Convection cells form in the atmosphere and in the oceans. This sets up powerful winds and currents that distribute the energy around the planet. Without this, most of the planet would be too hot or too cold for life.

radioactive describes atoms that are unstable and emit a particle to remove excess energy. These particles are capable of ionising other atoms upon collision, which can cause harm to living tissue.

mantle solid but soft middle rock layer of the Earth

plate tectonics a scientific theory that describes the relative movements and interaction of plates of the Earth's crust over the underlying mantle

CASE STUDY: The El Niño cycle

The convection cells set up in the oceans often move around with a semi-predictable pattern or **climate cycle**. El Niño is a climate cycle in the Pacific Ocean that can seriously affect weather patterns in the area. El Niño cycles typically occur every 3 to 5 years, bringing warmer ocean temperatures that boost eastern Pacific hurricanes, leading to more active (and damaging and costly) tropical storm seasons.

climate cycle any recurring pattern in global or regional climate

FIGURE 9.18 When an El Niño convection event forms it can lead to severe weather events.

9.4.3 Climate change and the effect of radiation

The science behind **climate change** is undeniable and quite simple. As described earlier, light energy can interact with matter in one of three ways and can be thought of as hitting a target:

- **Reflection** — it may bounce off the target.
- **Transmission** — if the energy is high enough it may pass through the target.
- **Absorption** — if the energy is within a narrow range it may be absorbed by the target without passing through.

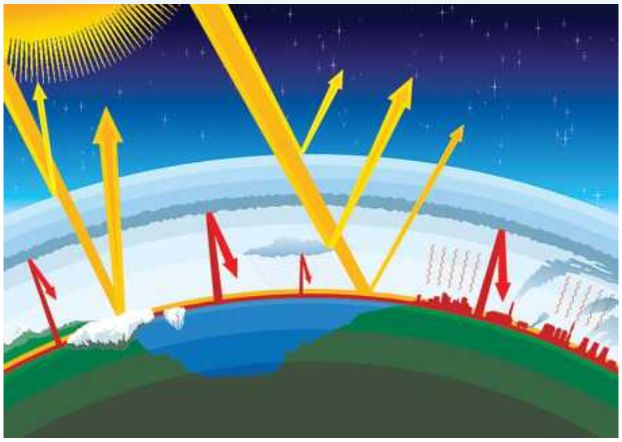
Light from the Sun hits the Earth. What happens to the energy?

- Some of this energy is reflected into space by the clouds before it hits the Earth's surface.
- Some of the energy is reflected back up into space from the Earth's surface.
- Some of the energy is absorbed by the Earth heating up the Earth.

All objects give off radiant heat; the Earth is no different. This means that the Earth radiates energy into space as well. The hotter the Earth gets the more it radiates. Eventually we get to a balance between energy coming into the Earth and energy going out to space.

It has been known for over a hundred years that if this were the end of the story, the average temperature of the Earth would be about –18 °C. So why is the Earth not frozen?

FIGURE 9.19 The temperature of the Earth depends upon the delicate balance between incoming solar radiation and outgoing radiant heat of the Earth. The atmosphere acts like a blanket keeping the Earth warmer than it should be.



climate change the alteration of climate patterns on local and global scales. This is not the same as changing weather.

The answer is the **greenhouse effect**. Some molecules in the Earth's atmosphere absorb infra-red radiation. The waves have just the right energy to get 'stuck' in the molecule and cause it to vibrate. Sometime later the molecule will re-emit the radiation in a random direction, which means that a lot of radiation that should have gone into space is redirected back to the Earth's surface. This keeps the Earth at an average temperature of 15 °C. (This is a similar process as in a greenhouse, hence the name.)

greenhouse effect the heating of the atmosphere due to the presence of carbon dioxide, methane and other gases

enhanced greenhouse effect the additional heating of the atmosphere due to the presence of increased amounts of carbon dioxide, methane and other gases produced by human activity

SCIENCE AS A HUMAN ENDEAVOUR: The enhanced greenhouse effect

Unfortunately, industrial and agricultural processes over the last two centuries have resulted in a significant increase in gases that absorb infra-red radiation. We call gases like carbon dioxide and methane 'greenhouse gases'. This means that the atmospheric blanket around the Earth is getting thicker. More radiation is being re-directed back towards the surface, which is heating up. This is called the **enhanced greenhouse effect**. This extra energy in our oceans and our atmosphere is now starting to drastically affect our world. These changes and the process is known as climate change. We are now in a technological race against time to limit the damage that our polluting ways have caused. We need to reduce the amount of greenhouse gases we produce, and make sure that we are using the limited resources of our planet in the best possible way.

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9.4 Exercise

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Select your pathway

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

Remember and understand

1. **MC** What causes plate tectonics?
   A. Earthquakes
   B. Conduction of heat from the core
   C. Convection of heat from the core
   D. Radiation of heat from the core
2. Why does the hot magma rise and create a convection cell?
3. Fill in the blanks to complete the sentence.
   It is _________ at the _________ than the equator because radiant heat from the _________ is _________ concentrated at the equator and spread out more at the _________.
4. Sketch a diagram showing what can happen to the energy that the Earth receives from the Sun?

Apply and analyse

5. Would it be a good idea to remove all of the carbon dioxide from the atmosphere? Explain your answer.
6. Mars has cooled more quickly than the Earth as it is smaller and cannot produce radioactive heat as quickly. The core is now solid and Mars has very little magnetic field. What effect do you think this had on Mars?

Evaluate and create

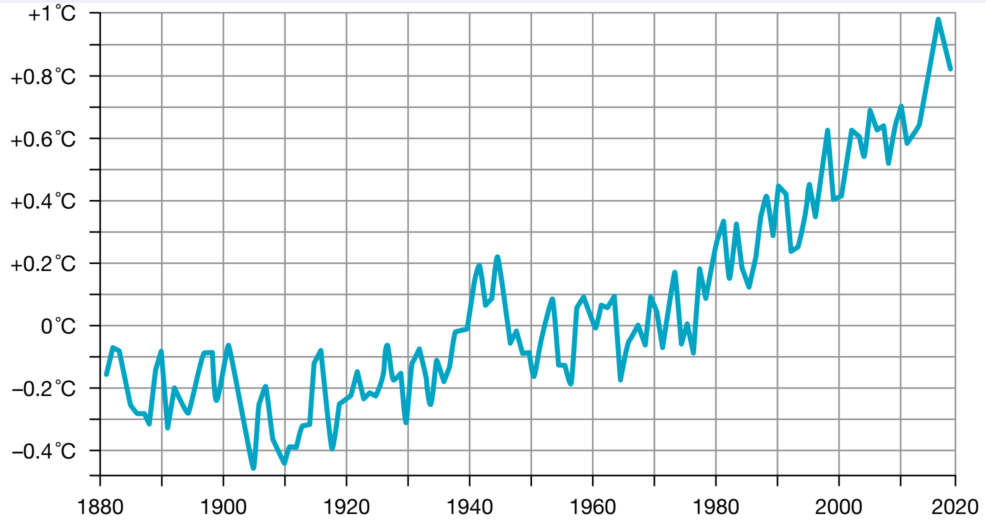
7. SIS The table shows the energy-related carbon dioxide emissions in 2011 from selected countries. In your opinion, who are the 'climate culprits' who are most responsible for the greenhouse effect? Discuss and back up your opinion with arguments.

TABLE Carbon emissions per country

Country	Total in million tonnes CO_2	Change between 1990 and 2011	Per inhabitant in tonnes CO_2
China	7999.6	+251.2%	5.9
USA	5287.2	+8.6%	16.9
India	1745.1	+199.7%	1.4
Russia	1653.2	–24.1%	11.7
Japan	1186.0	+11.7%	9.3
Germany	747.6	–21.3%	9.1
Canada	529.8	+23.7%	15.4
Great Britain	443.0	–19.3%	7.1
Indonesia	425.9	+191.6%	1.8
Brazil	408.0	+112.1%	2.1
Australia	396.8	+52.6%	17.4

8. SIS The graph shows the change in global temperatures over the last 140 years. Describe the trend that you see and hypothesise what has led to this trend. Can you observe and explain any periods of time that do not follow the trend perfectly? Predict what will occur in the next 80 years if the trend that you observe continues.

Average global temperature change



Fully worked solutions and sample responses are available in your digital formats.

9.5 Matter and energy — Waves

LEARNING INTENTION

At the end of this subtopic you will be able to describe a wave in terms of its nature, frequency and amplitude.

9.5.1 Transmitting energy with waves

When a wave is made in a still lake by dropping a rock into it, the wave spreads out. However, the particles of water do not move along the surface — they just move up and down. A duck sitting on the pond will just bob up and down when the wave hits it. Energy has been transmitted from the rock to the duck by the wave, without any movement of the matter in between. A **wave** is able to transmit energy from one place to another without moving any matter over the same distance.

DISCUSSION

Why do you sometimes see people in movies fishing using dynamite? What is the connection between this situation and waves?

9.5.2 Two types of vibrations

Waves travel by vibrations. Vibrations can be either forwards and backwards or up and down.

Transverse waves

If a vibration goes up and down sending a wave out at right angles to the vibration, we call this a **transverse wave**. Transverse waves can be made on a slinky. As shown in the figure 9.20, the moving particles in a transverse wave travel at right angles to the direction of energy transfer.

Examples of transverse waves are:
- ripples on a pond
- vibrations of the string
- light
- S-waves in earthquakes (shakes buildings side to side).

Longitudinal waves

If a vibration goes forwards and backwards and the energy is carried away in the same direction, we call this a **longitudinal wave**. It is sometimes called a **compression wave** as the particles need to be compressed to send a pulse.

Examples of longitudinal waves are:
- shock waves
- P-waves in earthquakes (pushes buildings up and down)
- sound waves.

9.5.3 Two types of waves

Another distinction that is useful in waves is their method of transport for the energy.

- **Mechanical waves** require particles to carry the energy.
- **Electromagnetic waves** do not need particles to carry the wave. They transfer their energy using **fields**, as we will see later.

wave the transmitter of energy without the movement of particles from place to place. The vibration of particles or energy fields is involved.

transverse wave a wave involving the vibration of particles perpendicular to the direction of energy transfer

longitudinal wave *see* compression wave

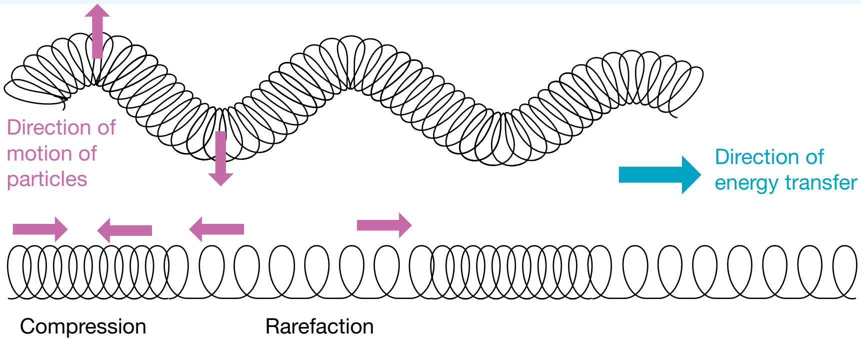
compression wave a wave involving the vibration of particles in the same direction as energy transfer

mechanical waves waves carried by the vibration of particles of matter

electromagnetic waves electromagnetic energy that is transmitted as moving electric and magnetic fields. There are many different types of electromagnetic energy; for example, light, microwaves, radio waves.

fields regions around an object in which each point is affected by a force of some type

FIGURE 9.20 Two types of energy transfer: a transverse wave (top) and a compression wave (bottom). The transfer of sound energy can be modelled using compression waves in a slinky.



If a wave requires particles to carry the energy, those particles are referred to as the **medium**.

EXTENSION: What is the medium?

Medium has nothing to do with size. It originally meant 'the thing in the middle'. That is why we have the word **'media'** (newspapers, TV reports, web articles), meaning the thing that is in the middle between something happening and you finding out. The medium in physics is the thing between the vibrating object and the thing that detects the energy.

9.5.4 Measuring waves

As always in science, we need to measure something before we can figure out how it works and how we can use it. Imagine a world where nobody had done this. We would have none of the modern communication technology that we enjoy today.

The most important properties of a wave to measure are **wavelength**, **frequency** and **amplitude**. How they are measured in transverse and longitudinal waves is shown in figure 9.21.

Wavelength

When a vibration occurs in a transverse wave, something is vibrating up and down. In one vibration it will make one wave. How far that wave travelled in that time is the wavelength. To find the wavelength, you measure the distance between two peaks, or two troughs, or the distance between any two corresponding points on neighbouring waves (figure 9.21).

In the case of a compression wave, the wavelength is the distance between the centre of two neighbouring **compressions** (high pressure), or two neighbouring **rarefactions** (low pressure). The wavelength of sound made during normal speech varies between approximately 5 centimetres and 2.5 metres.

medium a material through which a wave moves

wavelength distance between two neighbouring crests or troughs of a wave. This is the distance between two particles vibrating in step.

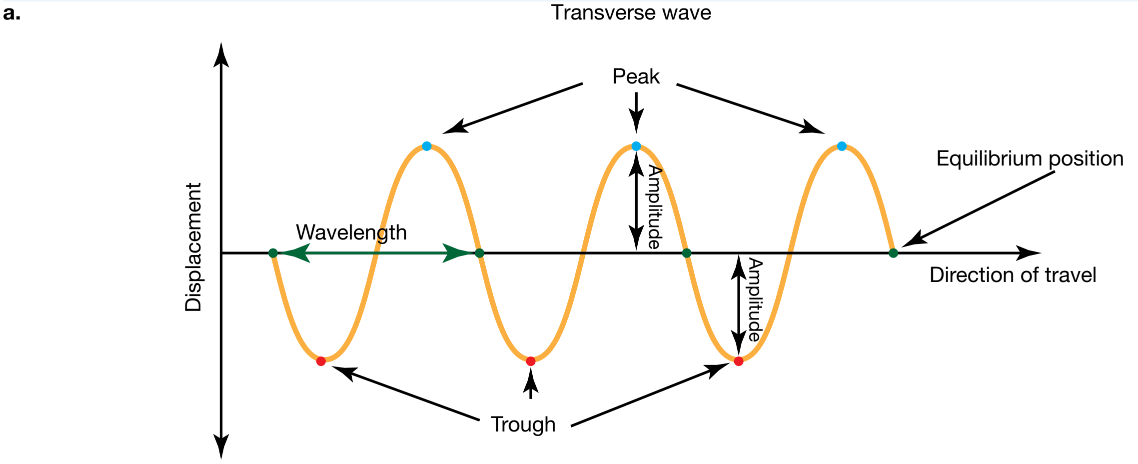
frequency the number of vibrations in one second, or the number of wavelengths passing in one second

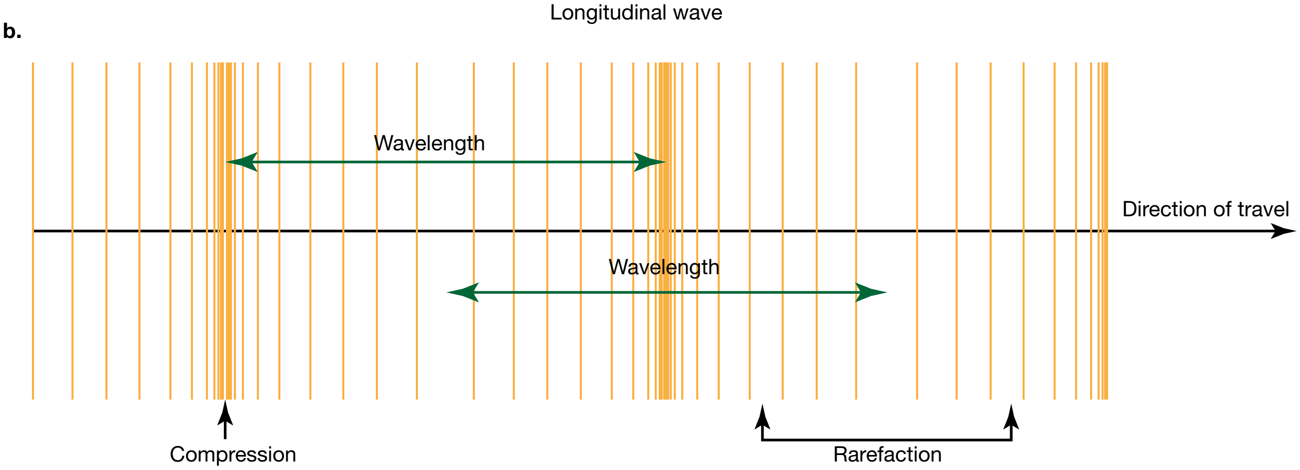
amplitude the maximum distance that a particle moves away from its undisturbed position

compression a region in which the particles are closer than when not disturbed by a wave; a squeezing force

rarefaction a region in which the particles are further apart than when not disturbed by a wave

FIGURE 9.21 Representations of **a.** transverse and **b.** longitudinal waves





Frequency

How often (frequently) do you eat a meal? If you eat breakfast, lunch and dinner then you have a meal frequency of 3 meals per day.

In the same way, the frequency of a vibration or wave is the number of complete vibrations or waves made in one second. In everyday language we call frequency **pitch**. High-frequency vibrations produce high pitch, and low-frequency vibrations produce low pitch. The unit of frequency is the hertz (Hz). A frequency of 1 Hz means one vibration per second.

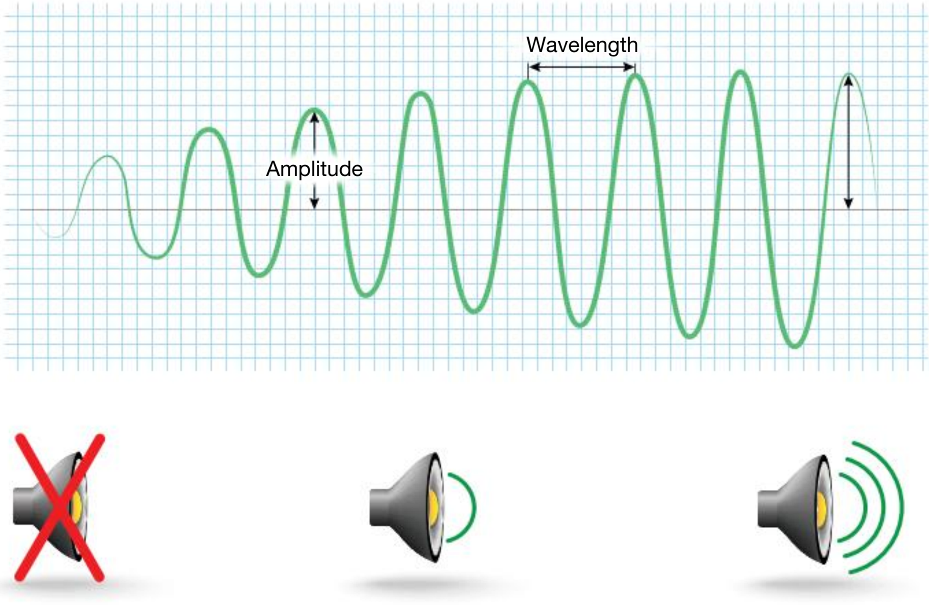
pitch how our hearing interprets frequency. High frequency vibrations are perceived as high pitch, low frequency waves are perceived as low pitch.

As the frequency of a sound gets higher, that is, as more compressions are produced per second, the compressions become closer together.

Amplitude

The amplitude of a wave is the maximum distance that each particle moves away from its usual resting position. In sound waves, higher amplitudes correspond with louder sounds due to the higher pressure in the compressions. If we plot a graph of how pressure changes, we can represent a longitudinal wave as a transverse wave (figure 9.22).

FIGURE 9.22 Longitudinal wave represented as a transverse wave showing how the amplitude changes as the volume of a sound increases.



As amplitude requires a particle to move, it only really makes sense to measure this in mechanical waves.

elog-0278

INVESTIGATION 9.3

Moving energy without matter

Aim

To model sound using waves on water and a slinky

Materials

- deep tray
- ribbon
- small cork
- slinky
- eye dropper
- water

Method

1. Half fill the tray with water and place a small cork on the water's surface. Use the eye dropper to release drops of water near the cork. Observe the motion of the cork and the motion of the small waves made by the drops.
2. Tie a ribbon around a coil near the centre of the slinky. Firmly hold one end of the slinky while your partner, holding the other end, stretches it to about the length of the room. Make a wave by rapidly flicking one end of the slinky to one side. Observe the ribbon as the wave passes.
3. Make a different type of wave by pulling about 10 coils of the slinky together at one end and then releasing this compressed section. Observe the ribbon as the wave passes.

Results

1. Describe the motion of the cork on the small waves.
2. Describe the motion of the ribbon as the waves made by flicking move along the slinky.
3. Describe the motion of the ribbon as the compression wave moves along the slinky.

Discussion

1. Is there any evidence to suggest that any water moves in the same direction as the waves?

2. In each of the slinky waves produced in this experiment, energy is transferred from one end of the slinky to the other.
   a. Where is the ribbon after the wave has passed in each case?
   b. Has any particle on the slinky moved from one end to the other?
3. Which properties of sound waves can be modelled by waves on water?
4. Identify strengths and limitations of this model.

Conclusion

What conclusions can you make about the similarity of sound waves and water waves?

on Resources

eWorkbook Waves (ewbk-3841)

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9.5 Exercise

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Select your pathway

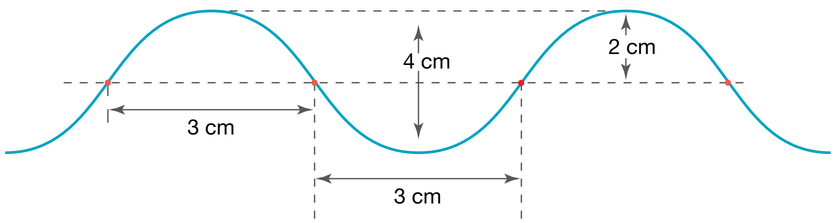
LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2	Questions 3, 4	Questions 5, 6

Remember and understand

1. MC What causes all sound waves?
   A. Vibrations
   B. Echoes
   C. Compressions
   D. Rarefactions
2. Fill in the blanks to complete the sentence.
   A compression is a region of _________ pressure where the particles are _________ together, and a rarefaction is a region of _________ pressure where the particles are more _________ apart.
3. MC What is the unit of frequency and what does it measure?
   A. Hertz (Hz) — the length of the wave
   B. Metres (m) — the length of the wave
   C. Hertz (Hz) — the loudness of the wave
   D. Hertz (Hz) — the number of vibrations per second.

Apply and analyse

4. What is the wavelength and amplitude of the transverse wave shown in the diagram?



Evaluate and create

5. Draw and label a wave with twice the frequency but the same amplitude as the wave in question 4.
6. Draw and label a wave with half the frequency and twice the amplitude as the wave in question 4.

Fully worked solutions and sample responses are available in your digital formats.

9.6 Energy transfer by sound

LEARNING INTENTION

At the end of this subtopic you will be able to describe sound as a pressure wave in a medium and calculate its speed.

9.6.1 A happy medium

Imagine that you are on a spacecraft on the way to Mars and a passing asteroid explodes. Would you hear the explosion before or after you saw it? Or would you even hear it at all?

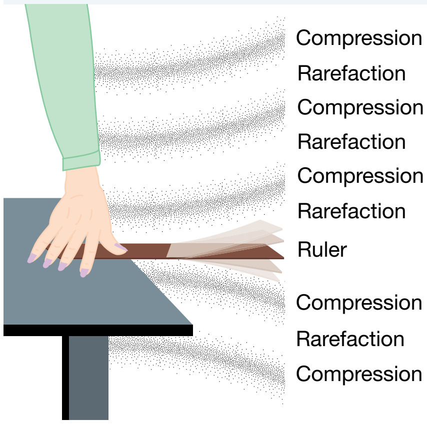
Because sound is transmitted as a compression wave, it can travel only through a medium that contains particles that can be forced closer together or further apart. Sound cannot be transmitted in a vacuum because there are no particles to push closer together or spread out.

As sound travels through a medium, some of its energy is absorbed by the particles in the medium and is not transmitted to neighbouring particles. Sound travels more efficiently through materials that are elastic; that is, materials in which the particles tend to come back to their original positions without losing much energy.

9.6.2 Sound waves

Sound is a compression wave. All sounds are caused by **vibrations**. Vibrations cause air to compress (like the lower wave pattern shown in figure 9.21). Figure 9.23 shows how a vibrating ruler makes compression waves in air. As the ruler moves up, a *compression* is created as air particles above the ruler are pushed together. Air particles below the ruler are spread out, creating a *rarefaction*. When the ruler moves down, a rarefaction is created above the ruler, while a compression is created below it. Each vibration of the ruler creates new compressions and rarefactions to replace those that are moving through the air.

FIGURE 9.23 Sound is a compression wave caused by vibrations.



vibrations repeated, fast back-and-forth movements

9.6.3 Speed of sound

The speed of sound in a particular medium depends on how close the particles are to each other and how easy they are to push closer together. In liquids and solids, the speed is much greater because the particles are more closely bound together. Table 9.1 shows the speed of sound in some common substances at 0 °C.

TABLE 9.1 Speed of sound in some common substances

Substance	Speed of sound (metres per second)
Carbon dioxide (at 0 °C)	260
Dry air (at 0 °C)	330
Hydrogen (at 0 °C)	1300
Water	1400
Sea water	1500
Wood	4000–5000
Glass	4500–5500
Steel	5000
Aluminium	5000
Granite	About 6000

SAMPLE PROBLEM 1 Finding the distance from a sound

If we see a distant flash of light from, for example, a firework, we can calculate how far away it is by timing how long it takes the sound to get to us. As light travels at 300 000 000 metres per second, we can assume that the time it takes for the light to reach us is zero.
If it takes 2 seconds to pass between flash and bang, how far away is the firework?

THINK	WRITE
1. Use the simple equation for velocity.	$\text{velocity} = \dfrac{\text{distance}}{\text{time}}$
2. Rearrange the equation to find the distance.	$\text{distance} = \text{velocity} \times \text{time}$
3. If the air is dry, the speed is 330 m/s.	$\text{distance} = 330 \times 3$
4. This means the distance to the firework is:	990 m.

The speed of sound changes

When people say ‘the speed of sound’, which speed do they mean? Speed is different in all substances. Even when just talking about air, the speed of sound can change a lot depending on atmospheric conditions. The speed of sound in air is greater at higher temperatures. At sea level in dry air at 0 °C, it is about 330 metres per second. At a temperature of 25 °C, it is about 350 metres per second. The speed of sound in air is lower at higher altitudes. At an altitude of 10 kilometres above sea level, it is about 310 metres per second.

FIGURE 9.24 A jet flying faster than the speed of sound can form a condensation cloud.

elog-0280

INVESTIGATION 9.4

Sound in different media

Aim

To investigate the transmission of sound in different media

Materials

- ticking watch
- metre ruler
- teaspoon (or spatula)
- cotton thread (or light string)

Method

1. Place a ticking watch against your ear and listen to the tick. Have your partner slowly move the watch away from your ear until you can no longer hear the ticking.
2. Measure and record the distance from your ear to this point.
3. Place a metre ruler gently against the same ear and rest the watch on it against the ear. Have your partner slowly slide the watch along the ruler to a point where you can no longer hear the ticking.
4. Measure and record the distance from your ear to this point.
5. Tie about 80 cm of cotton thread to a teaspoon. Swing the teaspoon slowly so that it gently strikes the side of a bench, wall or cupboard. Listen to the sound made.
6. Place the free end of the cotton thread carefully against your ear and again gently strike the teaspoon against the same surface. Listen to the sound made.

Transmitting sound

Results

1. Record the distance from the ticking watch to your ear when you can no longer hear the sound.
2. Record the distance on the metre ruler when you can no longer hear the watch ticking.
3. What did you observe when the cotton thread and spoon was struck against the bench, and when the thread was placed against your ear and the spoon was struck against the bench?

Discussion

1. What effect did the ruler have on the distance over which you could hear the sound of the ticking watch?
2. What difference does the cotton thread make to the sound heard when the spoon strikes a surface?
3. Is sound conducted better through air or through solids?
4. What property of the solids do you think makes the difference?

Conclusion

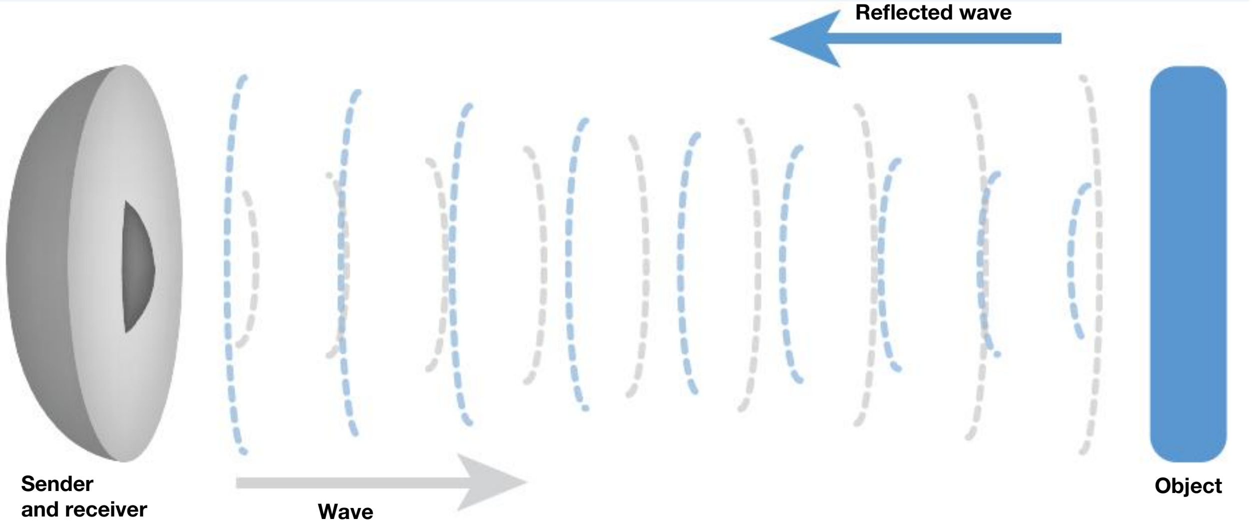
What conclusion can you make about how sound travels in different mediums?

9.6.4 Echoes in nature

An **echo** is what we call the reflection of a sound wave. We can estimate the distance between ourselves and a large object by shouting and timing how long it takes for the echo to return.

echo sound caused by the reflection of sound waves

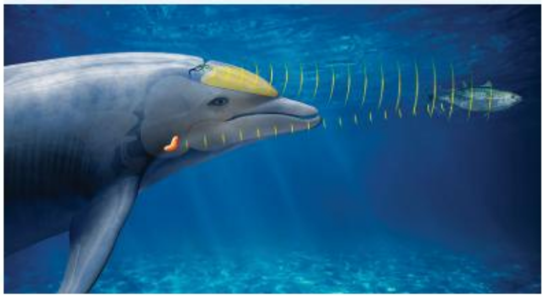
FIGURE 9.25 In all echoes a sound that is sent out is reflected back from an object and detected by the object that originally produced the sound.



The only difference between finding the distance to an object making a noise and an object reflecting a noise is that we must *halve* the time measurement as the distance the wave travels is *twice* the distance between the sound emitter and the sound reflector.

Many animals use echoes to find their way in the dark or to hunt their prey. This is called **echolocation** and is used by animals such as bats and dolphins.

FIGURE 9.26 Dolphins hunt in deep, dark water by mapping their surroundings using echoes.



DISCUSSION

How can bats hunt their prey in complete darkness?

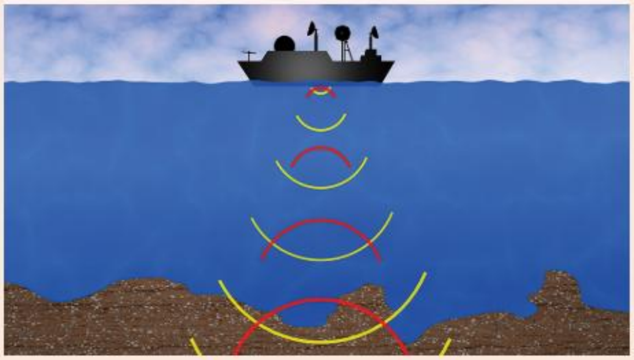
echolocation the use of sound to locate objects by detecting echoes

9.6.5 Technology and echoes

SCIENCE AS A HUMAN ENDEAVOUR: Using echoes

We could not have learned about the movement of the Earth's crust if we had not mapped the bottom of the oceans. The technology allowed us to understand the structure of the planet, the formation of Earth's magnetic field and allowed us to map 70 per cent of the planet's surface, which is hidden under the water. That exact same technology is also used to see inside the womb and build pictures of a baby without causing harm, and is now being used to let the blind see.

FIGURE 9.27 SONAR mapping the sea floor



SONAR

A knowledge of the speed of sound is used in **SONAR**. SONAR (Sound Navigation And Ranging) is used on ships to map the ocean floor, detect schools of fish, and locate other underwater objects such as shipwrecks and submarines. The process is:

- high-frequency sound is transmitted from the ship
- measure the time taken for the echo to return to the ship
- use the speed of sound in water to calculate the distance to the floor of the ocean or to the underwater object
- remember that the time taken is the time for the pulse to go to the sea-bed (floor) and back so it must be halved
- by adding many measurements you can map the sea floor
- higher frequency waves have smaller wavelengths so can be used to form an image in more detail.

SONAR the use of reflected sound waves to locate objects under water (sound navigation and ranging)

ultrasound sound with frequencies too high for humans to hear

Ultrasound

Although called by a different name, echolocation is also used by engineers to locate cracks in metals; and it is used extensively in medicine. The high-frequency sound used in industry and in medicine is called **ultrasound**. Ultrasound has frequencies higher than humans can hear. Echolocation with ultrasound is used in medicine to produce images of unborn babies in the womb during pregnancy, to search for circulation problems, remove some cancers, treat an eye condition called glaucoma, shatter kidney stones and gallstones in a process called shockwave therapy, and speed up the healing of muscle damage. It can also be used to clean surfaces, mix paint, homogenise milk and cut into glass and steel.

FIGURE 9.28 A modern 3-dimensional ultrasound is used to produce an image of the face of a full-term baby in the womb.

Humans can echolocate

There have been cases of humans who can echolocate. A growing number of people with severe vision impairment have begun clicking with their tongues. Their brains adapt to become able to perceive the slight difference in the sound when reflected back at them from different surfaces. Some become so good at the talent that they can ride a bike down a street whilst safely detecting and avoiding obstacles. Try echolocating yourself by closing your eyes and clicking your tongue in an empty space, then do it again while holding a book in front of your face. You should be able to hear the difference. There are also glasses in development that use echolocation to activate pins in a pad stuck to the tongue. This effectively prints a picture of the world on the tongue, which the brain learns to interpret as an image.

SAMPLE PROBLEM 2: Using SONAR to determine depth of the water

A SONAR pulse is sent out from a ship and returns 0.5 seconds later. Given the speed of sound in sea water is 1500 m/s, what is the distance to the sea-bed?

THINK	WRITE
1. Use the simple equation for velocity.	$\text{velocity} = \dfrac{\text{distance}}{\text{time}}$
2. Rearrange the equation to find the distance.	$\text{distance} = \text{velocity} \times \text{time}$
3. The SONAR pulse took 0.5 seconds to reach the sea-bed and return back to the ship. If we halve the time we know how long it took for the pulse from the ship to reach the sea-bed.	$\dfrac{0.5}{2} = 0.25$ seconds
4. The speed of sound in sea water is 1500 m/s.	$\text{distance} = 1500 \times 0.25$
5. The distance from the ship to the sea bed is:	375 m.

on Resources

assess on Additional automatically marked question sets

9.6 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Why are sound waves unable to travel through a vacuum?
2. What is ultrasound and how is it useful?

Apply and analyse

Use the data given table 9.1 to answer questions 3–5.

3. SIS In general, how does the speed of sound in solids compare with that in liquids and gases?
4. SIS Identify the substance that doesn't seem to fit the pattern. Give comparison values to demonstrate why this value seems anomalous.
5. SIS Why do you think such a large range of speeds is given for wood? How could you investigate whether your answer is correct?
6. Why do you think high-frequency waves give better detailed pictures?
7. Suggest why the speed of sound depends on altitude and temperature.

Evaluate and create

8. Imagine that you are one of two astronauts walking on the moon.
   a. Would you be able to conduct a conversation with your partner without radios? Explain why.
   b. Imagine that both of your radios stopped working because you forgot to recharge the batteries. Explain how you would still be able to speak with your partner (no sign language or writing allowed).
9. Imagine that you are standing near a steep, rocky cliff. You shout 'Hello' and one second later you hear the echo. The air temperature is about 25 °C, so you estimate that the speed of sound is about 350 m/s. How far are you from the cliff?
10. A ship sends a SONAR pulse down into the water. After 0.2 seconds an echo is detected. You estimate that the speed of sound is about 1500 m/s. How deep is the water?
11. The speed of sound in air at a temperature of 25 °C is about 350 m/s. How long would it take for sound waves to travel from Melbourne to Sydney, a straight distance of about 700 km, when the air temperature is 25 °C?

Fully worked solutions and sample responses are available in your digital formats.

9.7 Hearing sound

LEARNING INTENTION

In this subtopic you will investigate how the ear works and explain how it can be damaged.

9.7.1 The ear

The energy of sound waves is transformed by your ear into electrical signals that are sent to your brain. Each of your ears has three distinct parts — the outer ear, middle ear and inner ear. Each part has its own special job to do.

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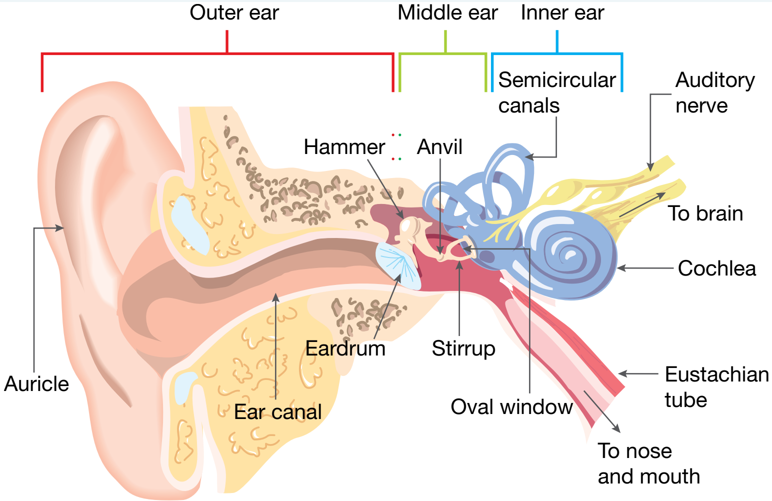
FIGURE 9.29 Parts of the human ear



Outer ear

The fleshy, outer part of the ear is called the **auricle**. This collects the sound energy more efficiently than a simple hole in the head would. The outer ear funnels the energy of the vibrating air through the **ear canal** to the **eardrum**. The eardrum is a thin flap of skin, or **membrane**, which vibrates in response to the changing pressure of the vibrating air particles.

Middle ear

The middle ear contains three small bones called the hammer, the anvil and the stirrup. These three tiny bones (known as the **ossicles**) pass on the vibrations to the inner ear through the **oval window**.

Inner ear

The inner ear contains the **cochlea** and the **semicircular canals**. The cochlea is a spiral-shaped system of tubes full of fluid. When vibrations are passed through the oval window by the stirrup, the fluid moves tiny hair-like cells inside the cochlea. The hairs respond to specific frequencies only so that we can make sense of the different sounds that we hear. These hairs are attached to the receptor nerve cells that send messages on their way to the brain through the **auditory nerve**.

auricle the fleshy outside part of the ear

ear canal the tube that leads from the outside of the ear to the eardrum

eardrum a thin piece of stretched skin inside the ear that vibrates when sound waves reach it

membrane a thin layer of tissue

ossicles a set of three tiny bones that send vibrations from the eardrum to the inner ear. They also make the vibrations larger.

oval window an egg-shaped hole covered with a thin tissue. It is the entrance from the middle ear to the outer ear.

cochlea the snail-shaped part of the inner ear in which receptors are stimulated

semicircular canals three curved tubes, filled with fluid, in the inner ear that control your sense of balance

auditory nerve a large nerve that sends signals to the brain from the hearing receptors in the cochlea

The limits of hearing

For a human, the range of frequencies that we can hear, assuming normal hearing, is from 20 Hz to 2000 Hz. As you age you begin to lose the ability to hear the high frequencies as those haircells become damaged over time.

Other animals have different ranges of hearing. That is why dog whistles sound silent for us but loud for dogs. They can hear much higher frequencies than we can.

The semicircular canals

The semicircular canals also contain a fluid. However, they are not involved in hearing sound. When you move your head, the fluid in the semicircular canals moves hairs that send signals to your brain. The signals provide your brain with information to help you keep your balance.

FIGURE 9.30 Energy flow from sound wave to brain

Sound energy is collected by the auricle and channelled into the ear canal. → The sound energy is passed on to the eardrum as kinetic energy when it starts to vibrate. → The ear drum passes the energy on to the ossicles, which also vibrate and amplify the pressure. → The vibration is passed onto a liquid in the cochlea, which moves causing hairs to vibrate. → Each hair that vibrates sends electrical energy down the auditory nerve to the brain.

DISCUSSION

Beethoven was a famous composer of classical music who gradually lost his hearing. When he was completely deaf he could still compose music, but he did it with a pencil in his mouth that touched the piano. Discuss why you think he did this.

EXTENSION: Animal hearing

- The African elephant's ears enable them to hear low-pitched sounds from other elephants over 4 kilometres away. They also use their giant ears to release heat, sometimes flapping them to cool down more quickly.
- Some insects have ears but they are not on their heads. The ears are membranes like eardrums on the surface of their bodies. A cricket has an ear just below the knee of each of its front legs. A grasshopper has an ear on each side of its body just below the wing. Most other insects do not have ears but detect vibrations with sensitive hairs on their antennae or other parts of their bodies.

EXTENSION: Why your ears pop on a plane

When you are landing or taking off in a plane, or even travelling in a lift, your ears 'pop'. If you climb steeply, the air pressure inside your middle ear remains the same while the air pressure outside drops. The air inside pushes on the eardrum causing an uncomfortable feeling. The 'popping' is caused as the Eustachian tube, which is normally closed, opens. This allows air to rush out of your middle ear to your nose and mouth. The pressure is then the same on both sides of the eardrum. When you descend quickly, the 'popping' occurs as the air rushes into your middle ear to balance the increasing pressure outside. If you swallow hard, you can make the 'popping' happen sooner.

9.7.2 Loudness

Sound makes your eardrums vibrate. But if the sound is too loud, the vibrations can cause pain and even permanently damage your ear. That's because loud sounds carry more energy, disturbing the air — and your eardrums — more than soft sounds.

Although loudness can be a matter of opinion, the disturbance to the air can be measured.

- The measurement is called the **relative sound intensity**, or sound level.
- The unit of measurement is the **decibel (dB)**. The number of decibels gives a good indication of the loudness of a sound. It's not a perfectly accurate measure of loudness, because your ear is more sensitive to some pitches than others.
- The **threshold of hearing** is the smallest sound level that can be heard when the air is vibrating at 1000 Hz. For most people it's about 0 dB.
- The **threshold of pain** is the smallest sound level that causes pain. Sound levels of more than about 130 dB can cause pain and permanent ear damage. Sound levels of even 80 dB can cause damage to your ears if you are exposed to the sound for long enough.

relative sound intensity is a measure of the energy of a sound, which provides an indication of loudness. It is measured in decibels (dB) and is often referred to as sound level.

decibel (dB) a unit of measurement of relative sound intensity

threshold of hearing the lowest level of sound that can be heard by the human ear

threshold of pain the lowest level of sound that causes pain to the human ear

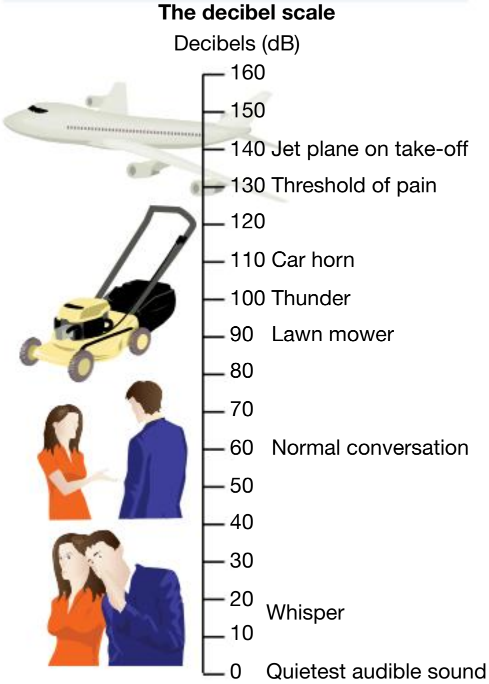
Hearing loss

There are many reasons why a person may not be able to hear. Temporary hearing loss may result from an infection, a build-up of earwax, a blow on the head or a loud noise.

Permanent hearing loss can be due to any of the middle or inner ear structures becoming damaged or not forming correctly at birth.

Hearing aids have been used for many years to make sounds louder for those with impaired hearing. The battery-operated hearing aid that some people wear amplifies the vibrations so that they can reach a properly working cochlea. Another type of hearing aid 'bends' the vibrations so that they go through a bone behind the ear to the cochlea (see 'Science as a human endeavour: The cochlear implant' that follows).

FIGURE 9.31 Sound level is measured in decibels (dB).



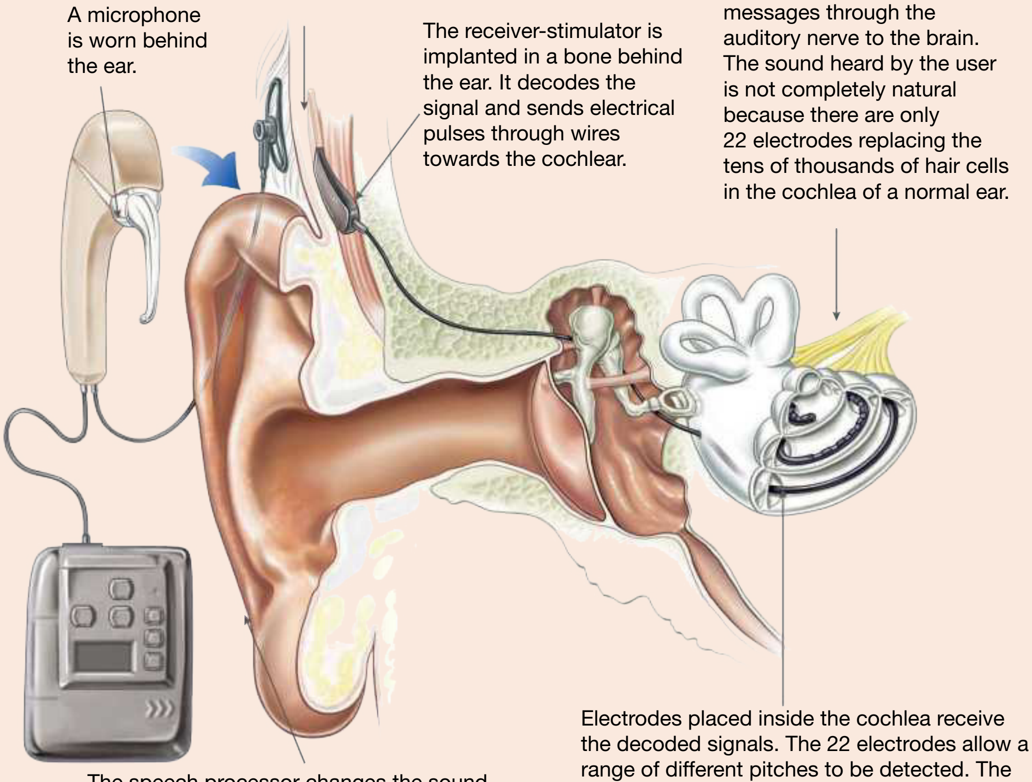
SCIENCE AS A HUMAN ENDEAVOUR: The cochlear implant

Many people who have severely or profoundly impaired hearing are unable to benefit from hearing aids. Profoundly hearing-impaired people hear no sounds at all.

Australian scientists have developed a device that has allowed some people who are profoundly hearing impaired to detect sound for the first time in their lives. The cochlear implant, or bionic ear, is surgically placed inside the ear. A microphone worn behind the ear detects sound and sends a signal to the speech processor (a small computer worn in a pocket or on a belt). It converts the sound into an electrical signal that is sent to a receiver behind the ear and on to the implant in the cochlea. The signal then travels along the auditory nerve to the brain.

FIGURE 9.32 Bionic ear headset and speech processor

FIGURE 9.33 How cochlear implants work



CASE STUDY: Ringing in your ears

If you've ever been to a really loud concert, you may have experienced ringing in your ears afterwards. You would also have had trouble hearing. Even after you had gone home to bed and the house was silent, the ringing would still have been there.

This ringing in your ears is called **tinnitus** (sometimes pronounced tin-eye-tus). Some of the cells in your inner ear — the ones that detect vibrations — have been damaged. Fortunately, your ears are likely to recover. The ringing will stop and your hearing will return to normal — hopefully in a few hours, but maybe in a day or two. If you listen to loud music for too long or too often, the cells don't recover. Your hearing can be permanently damaged. It's a good idea to avoid this by wearing earplugs at loud concerts.

tinnitus a ringing or similar sensation of sound in the ears, caused by damage to the cells of the inner ear

FIGURE 9.34 Ear protection is needed when working with noisy machinery, including racing cars.

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INVESTIGATION 9.5

Making it seem louder

Aim

To investigate a method of making a sound seem louder

Materials

- ticking watch
- sheet of paper, about A4 size
- metre ruler
- blindfold

CAUTION

Take care not to put the funnel into the ear canal.

Method

1. Blindfold your partner and have them sit on a chair.
2. Hold a ticking watch close to your partner's right ear. The left ear should be covered with an open palm.
3. Move slowly away until your partner indicates that the sound of the ticking watch can no longer be heard.
4. Measure and record the approximate distance from the watch to your partner's right ear.
5. Make a funnel with a sheet of paper. Place the narrow end of the funnel close to, but not touching, your partner's right ear. Your partner should be able to hold it in place.
6. Again, move the ticking watch slowly away from your partner, starting near the wide end of the funnel, until it can no longer be heard.
7. Measure and record the approximate distance between the watch and your partner's right ear.

Results

1. Record the distance from the watch to your partner's ear without the funnel.
2. Record the distance from the watch to your partner's ear with the funnel.

Discussion

1. What difference does the funnel make?
2. How does the funnel work?
3. Look at your own ears. Why do you think they are that shape?

Conclusion

What can you conclude about the ability to make a sound seem louder?

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INVESTIGATION 9.6

Sound proofing

Aim

To investigate the effect of different materials on the transmission of sound

Materials

- variety of materials to test (such as wood, fabric, glass and cardboard)
- source of sound (such as an MP3 player)
- sound level meter or data logger and sound probe

Method

Design an experiment to investigate the most effective material to insulate against noise.

Results

Record your results in a suitable table and graph.

Conclusion

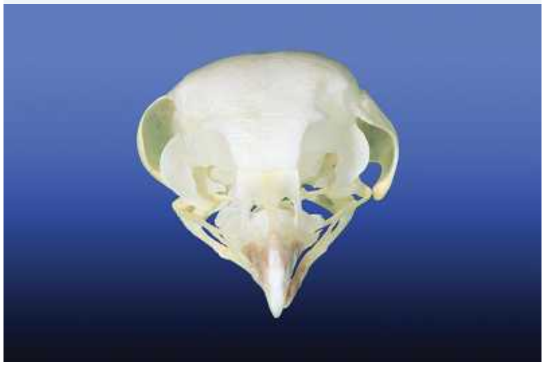
Analyse your results to draw an appropriate conclusion.

Why do we have two ears?

Incredibly our brains can tell the difference in arrival time of a sound between our two ears. This allows us to figure out roughly where a sound is coming from. This is called **binaural hearing**.

Owls have taken this one step further. Their ears are at different heights, giving them a 3-dimensional sense of sound. They can target the squeaks of a bat, not just to the left and right but also up and down.

FIGURE 9.35 Adult skull of a boreal owl (*Aegolius funereus*) showing the marked asymmetry of the ears



9.7.3 Why do we like music but dislike noise?

Musical notes make repeating patterns that are predictable. The human brain likes to detect patterns and most cultures seem to have discovered music very early in their development.

binaural hearing sound detection in creatures with two ears in order to locate the source of a sound

However, noise has no repeated pattern in the frequencies and amplitudes of the sounds received by our brains. It puts us on edge, possibly for evolutionary reasons. Imagine our early ancestors being hunted through the jungle. Noise would make it hard to hear a predator. We have learned to use some noises to our advantage, warning sirens and alarms for instance.

Unfortunately, one of the 'side effects' of living in an industrialised world is noise. Some of this noise is loud enough to damage your ears. But some of it is just annoying. The offending noises come from sources that include:

- transport, such as aeroplanes, trains, trams, trucks, cars, buses and cars
- heavy machinery, such as tractors, bulldozers, harvesters and jackhammers
- entertainment venues, such as rock concerts, nightclubs and sporting events
- domestic sources, such as mowers, power tools and much, much more.

FIGURE 9.36 The effect of freeway noise on nearby residents is reduced by barriers that absorb and reflect sound energy.

With good planning and zoning, the noise of traffic, factories and entertainment venues can be kept away from residential areas, hospitals and schools. Sound barriers are built and trees planted beside freeways to reduce the noise heard by nearby residents. Sound barriers are designed to reflect and absorb sound energy. Trees are great natural absorbers of sound energy. State and local government laws restrict times when you can use mowers, power tools and other noisy items like air-conditioners and swimming-pool pumps. These laws vary from state to state and between local councils.

CASE STUDY: Noise-cancelling headphones

Noise-cancelling headphones work by listening to your surroundings and playing a noise into your ears that almost completely cancels out the sound that you would normally hear. If it detects a compression, it produces a rarefaction of the same amplitude. They are enjoyable to use for listening to your music in your bedroom without having to hear the vacuum cleaner downstairs. They are vital for the concentration of people in high pressure and noisy jobs, like fighter pilots.

on Resources

eWorkbook Sound energy (ewbk-3845)

assess on Additional automatically marked question sets

9.7 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. MC Why is the sound level measured in decibels not regarded as a completely accurate measure of loudness?
   A. You may be standing at different distances from the object.
   B. Everyone has different ears and hearing.
   C. Decibels are not as accurate as millibels.
   D. Your ears are more sensitive to some pitches than others.
2. MC The threshold of hearing is defined as:
   A. the closest you can stand in front of something making a loud sound
   B. the smallest sound level the typical ear can hear
   C. the highest sound level that you can listen to without pain
   D. the highest sound level that you can listen to without damage.
3. Complete the following table to describe some of the important structures of the human ear.

TABLE Structures of the human ear

Structure	Description	Purpose
Eardrum		
	Three small bones in the middle ear	
	An opening into the inner ear	Allows vibrations to pass into the cochlea
Cochlea		Contains receptor cells for hearing
		Allows air to move between the middle ear and the mouth and nose

Apply and analyse

4. Explain why luggage handlers who work on the tarmac at airports are required to wear ear protection.
5. Describe tinnitus and explain how it can be avoided.
6. Explain how the bionic ear is different from a normal hearing aid.
7. When you clap your hands, a sound is heard. Put these sentences in order to explain how the energy of the sound gets from your hands, through the air, through your ear and finally to your brain.
   A. The electrical impulses travel through the auditory nerve to the brain.
   B. When vibrations are passed through the oval window, they pass into the fluid in the cochlea, which moves tiny hairs.
   C. The eardrum vibrates in response to the vibrating air particles.
   D. When you clap your hands, air particles are displaced, forming a wave of changing air pressure.
   E. These hairs are attached to nerve cells that send messages in the form of electrical impulses
   F. The vibrating eardrum causes vibration in the ossicles that pass on the vibrations to the inner ear through the oval window.
   G. These vibrations travel through the air to the auricle of the ear, which channels the energy of the vibrating air through the ear canal to the eardrum.

Evaluate and create

8. SIS The table shows the safe amount of time that you can continuously listen to noises at different decibel levels.
   a. Plot the data as a chart.
   b. Describe the trend that you observe.
   c. Use your prediction to suggest how long you could safely listen to a 90 dB noise.

TABLE Noise level permissible exposure time

Continuous decibels (dB)	Permissible exposure time (hours)
85	8
88	4
91	2
94	1
97	0.5
100	0.25
103	0.125

Fully worked solutions and sample responses are available in your digital formats.

9.8 Energy transfer by light

LEARNING INTENTION

At the end of this subtopic you will be able to describe light as an electromagnetic wave and name the key regions of the spectrum. You should be able to describe the link between energy and frequency of the light.

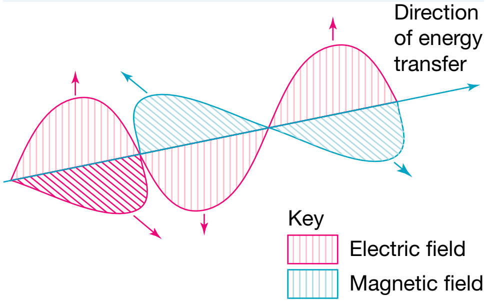
9.8.1 What is radiation?

Around any charged particle there is an electric field. If that charge moves, the electric field moves too, sending a ‘ripple’ through the field. We will see in a later topic that when you get a changing electric field you make a changing magnetic field. A changing magnetic field causes a changing electric field and so on.

This means that whenever a charged particle vibrates, for instance because it has heat energy, it will be producing a changing electromagnetic field that carries energy away. When this wave hits another charged particle it will be absorbed, causing the particle to vibrate.

The energy produced radiates away, i.e. travels in a straight line as if along a radius of a circle. That is why this form of energy is referred to as electromagnetic radiation. Visible light is one type of electromagnetic radiation.

FIGURE 9.37 A representation of part of an electromagnetic wave



9.8.2 The electromagnetic spectrum

Take a pen and draw a low-frequency wave from one side of a piece of paper to another. Use a stopwatch to time yourself doing this. When you are done, draw another wave of much higher frequency but the same amplitude *and taking the same amount of time*. Which drawing required more energy?

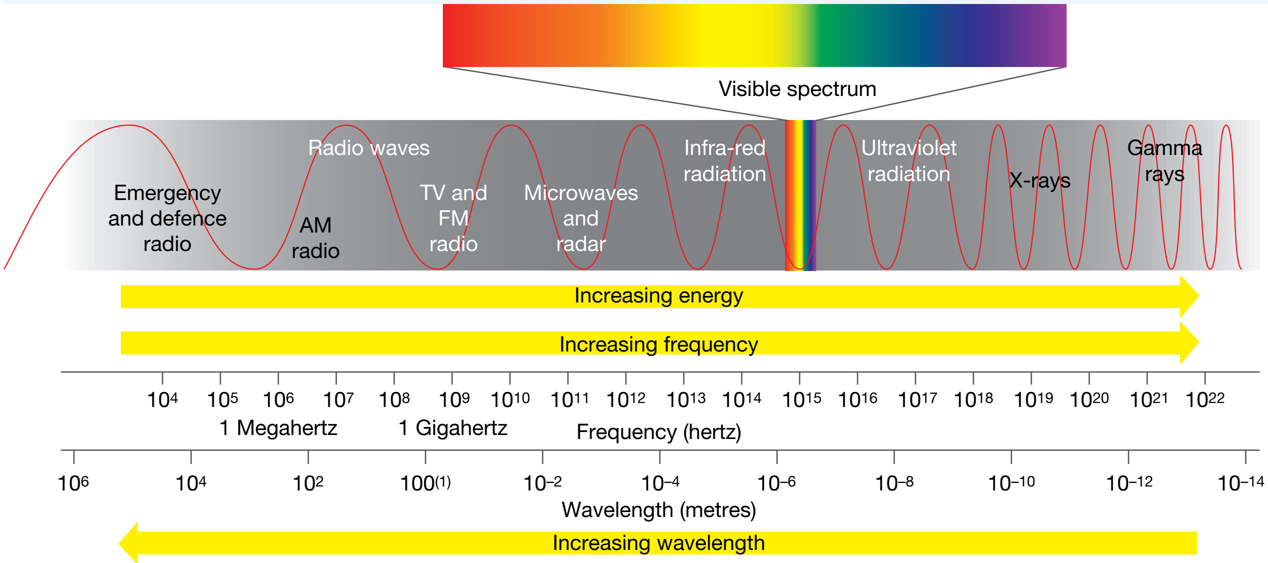
You should have found that high-frequency waves are also high-energy waves.
- Objects that are cold have little energy to lose and so produce long wavelengths, low-frequency electromagnetic radiation waves.
- The hotter an object is the higher the frequency, higher the energy and shorter the wavelength produced.

Despite their different energies, all types of light travel at the same speed in a vacuum. The speed of light and all other types of electromagnetic radiation is approximately 300 000 000 m/s. However, it does slow down when passing through matter. For example, light travels through glass at a leisurely 200 000 000 m/s.

There is a huge range, or *spectrum*, of energies of electromagnetic radiation that can be produced. These include:

- radio waves
- infra-red radiation
- visible light
- ultraviolet radiation
- x-rays
- gamma rays.

FIGURE 9.38 The electromagnetic spectrum



Radio waves

Radio waves include the low-energy waves that are used to communicate over long distances through radio and television. They also include radar and the microwaves used in microwave ovens for cooking.

radio waves low-energy electromagnetic waves with a much lower frequency and longer wavelength than visible light

EXTENSION: Can you hear the Big Bang?

Radio waves and microwaves are low energy and generally quite safe. You are constantly bathed in radiation left over from the Big Bang! You can hear evidence of this radiation when you tune a radio between stations.

Microwaves that are used to cook are actually tuned to be exactly the right frequency to be absorbed by water, making the water hotter and cooking the food from the inside.

Infra-red radiation

Infra-red radiation, invisible to the human eye, is emitted by all objects and is sensed as heat. The amount of infra-red radiation emitted by an object increases as its temperature increases.

FIGURE 9.39 A gentle push of the button sends infra-red radiation to the television set at 300 million metres per second.

Visible light

Visible light represents only a very small part of the electromagnetic spectrum. It is necessary for the sense of sight. The process of photosynthesis in green plants cannot take place without visible light.

Ultraviolet radiation

Like infra-red radiation, **ultraviolet radiation** is invisible to the human eye. It is needed by humans to help the body produce vitamin D; however, too much exposure to ultraviolet radiation causes sunburn as it has enough energy to penetrate the outer layers of skin and damage the delicate tissues underneath.

WHAT DOES IT MEAN?

The words *ultraviolet* and *ultrasound* are derived from the Latin term *ultra*, meaning 'beyond'. Ultraviolet radiation has frequencies beyond those of the colour violet, and ultrasound has frequencies beyond those of sounds we can hear.

X-rays

X-rays have enough energy to pass through human flesh. They can be used to kill cancer cells, find weaknesses in metals and analyse the structure of complex chemicals. X-rays are produced when fast-moving electrons give up their energy quickly. In x-ray machines, this happens when the electrons strike a target made of tungsten.

Some parts of the human body absorb more of the energy of x-rays than others. For example, bones absorb more x-ray energy than the softer tissue around them. This makes x-rays useful for obtaining images of bones and teeth. To obtain an image, x-rays are passed through the part of the body being examined.

infra-red radiation invisible radiation emitted by all warm objects. You feel infra-red radiation as heat.

visible light a very small part of the electromagnetic spectrum to which our eyes are sensitive

ultraviolet radiation invisible radiation similar to light but with a slightly higher frequency and more energy

x-rays high-energy electromagnetic waves that can be transmitted through solids and provide information about their structure

The x-rays that pass through are detected by photographic film on the other side of the body. Because bones, teeth and hard tissue such as tumours absorb more energy than soft tissue, they leave shadows on the photographic film, providing a clear image.

CT scanners (or CAT scanners) consist of x-ray machines that are rotated around the patient being examined.

FIGURE 9.40 X-ray showing a fracture of a radius and ulna in a forearm

Gamma rays

Gamma rays are unusual in that they are not made in the same way as other forms of light. Rather than being produced by vibrating atoms or accelerating electrons, they are made in nuclear decay. They have even more energy than x-rays and can cause serious damage to living cells. They can also be used to kill cancer cells and find weaknesses in metals. Gamma rays are produced when energy is lost from the nucleus of an atom. This can happen during the radioactive decay of nuclei or as a result of nuclear reactions.

SCIENCE AS A HUMAN ENDEAVOUR: Using gamma rays in medicine

Gamma cameras are used in PET scans to obtain images of some organs. To obtain a PET scan, a radioactive substance that produces anti-matter versions of electrons, called positrons, is injected into the body (or in some cases, inhaled). As it passes through the organ being examined, the positrons collide with electrons and annihilate each other in a microscopic nuclear explosion! This sounds bad, but the energies involved are small and you feel nothing. The explosion produces gamma rays, which are detected by the camera.

FIGURE 9.41 A patient undergoing a PET scan of her brain

DISCUSSION

If light can travel forever until absorbed and the universe is infinite, then there must be stars in every direction that we look. So why is the night sky black?

9.8.3 Comparing light and sound

Some differences between sound waves and electromagnetic waves are summarised in table 9.2.

TABLE 9.2 Comparison of sound waves and electromagnetic waves

Sound waves	Electromagnetic waves
Compression (longitudinal) waves	Transverse waves
Travel through all solids, liquids and gases, but are unable to travel through a vacuum	Unable to travel through some substances but travel through a vacuum
Speed in air between about 330 m/s and 350 m/s, depending on temperature	Speed in air about 300 000 000 m/s

on Resources

assesson Additional automatically marked question sets

9.8 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. **MC** Electromagnetic waves are:
   A. Longitudinal waves
   B. Compression waves
   C. Transverse waves
   D. Mechanical waves.
2. Fill in the blanks to complete the sentence.
   All electromagnetic waves have a number of things in common. They are all __________ waves, they can all travel through a __________ with a speed of approximately __________ m/s.
3. Fill in the blanks to complete the sentence.
   There are differences between sound waves and electromagnetic waves.
   Sound waves are __________ waves, whereas electromagnetic waves are __________ waves; sound waves need __________ to travel through, whereas electromagnetic waves do not; the speed of sound is much __________ than the speed of electromagnetic waves.
4. Arrange the following regions of the electromagnetic spectrum in order from the lowest energy to the highest energy.

   X–ray
   Infra-red
   Ultraviolet
   Gamma ray
   Visible light
   Radio waves

5. Arrange the following regions of the electromagnetic spectrum in order from the highest to the lowest frequency.

X–ray
Infra-red
Ultraviolet
Gamma ray
Visible light
Radio waves

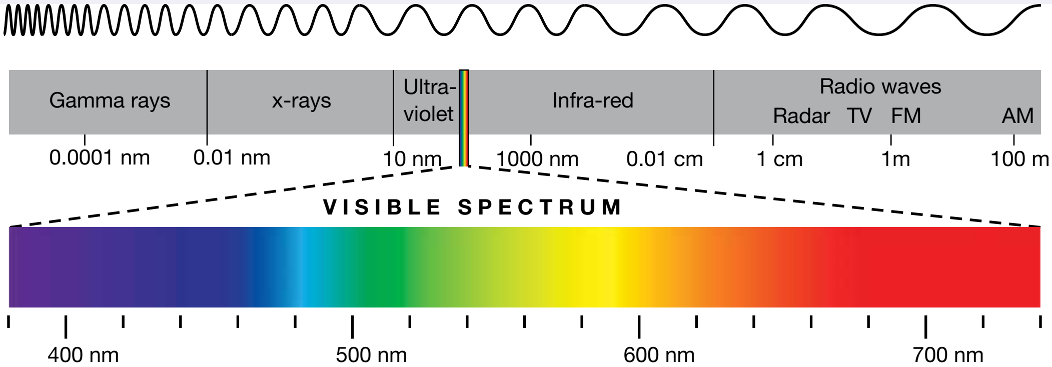
6. Arrange the following regions of the electromagnetic spectrum in order from the longest wavelength to the shortest wavelength.

X–ray
Infra-red
Ultraviolet
Gamma ray
Visible light
Radio waves

Apply and analyse

7. Explain why you always hear thunder after you see the lightning that caused it.
8. Use the figure to identify the types of electromagnetic radiation that have more energy than visible light?

The electromagnetic spectrum



A. Ultraviolet radiation
B. X-rays
C. Radio waves
D. Infra-red radiation
E. Gamma rays

Evaluate and create

9. MC Select the three properties of sound waves that make them different from electromagnetic waves.
   A. They are compression waves.
   B. They are transverse waves.
   C. They need particles to travel.
   D. They do not need particles to travel.
   E. The speed of sound is much smaller.
   F. The speed of sound is much larger.
10. Explain why the behaviour of electromagnetic waves cannot be modelled using compression waves in a gas or a slinky.

Fully worked solutions and sample responses are available in your digital formats.

9.9 Wave behaviour of light

LEARNING INTENTION

At the end of this subtopic you will be able to describe the behaviour of light during reflection and refraction.

9.9.1 Understanding water waves to understand light

In the distant past, people living at the coast observed that the waves on the ocean showed some predictable behaviour.

- Waves could *reflect* from a rock.
- As the water depth changed, waves would slow and often change direction in a process called *refraction*.
- Water waves clearly carried *energy*.

Eventually it occurred to scientists that as light also could reflect, refract and carry energy, maybe it too was a wave. In this section we look at how we can use the wave behaviour of light to our advantage.

FIGURE 9.42 Waves reflect, refract and carry energy.

EXTENSION: Using models to understand natural phenomena

The representation of light as waves is an example of a **model**. A model provides a useful way of investigating the properties and behaviour of something that you can't see.

During the seventeenth century, there were two 'opposing' models of light. One was a wave model similar to the one we use today. The other model, a particle model proposed by Sir Isaac Newton, was more popular at the time. Newton proposed that light consisted of a stream of tiny particles that he called corpuscles. This model successfully explained the reflection of light. However, the only way that Newton's model could explain light bending when it moves from air to water was if it travelled faster in water. Of course, at that time there was no way to measure the speed of light in water.
We now know that light travels more slowly in water.

The wave model is successful at explaining most properties of light. However, in the early twentieth century, Albert Einstein, more famous for his theories of relativity, explained how light could also be seen as a stream of particles, which were later named **photons**. Photons are 'packets of energy' that have properties of both particles and waves. We say that photons have **wave-particle duality**.

model simplified description, often a mathematical one, of a process

photon a particle such as a quantum of light or electromagnetism

wave-particle duality model that treats all objects as having both wave-like and particle-like properties. The property observed depends on the observation method chosen.

9.9.2 Ray tracing

DISCUSSION

What devices can you think of that redirect light for a useful purpose? How do they work?

Most of the objects that you see are **non-luminous**. **Luminous** objects are those that emit their own visible light. The Sun and the flame of a burning match are examples of luminous objects. However, non-luminous objects will still produce light of lower energies that our eyes cannot see. Once this light has been emitted, how can we determine where it will go?

Light travels in straight lines as it travels through empty space or through transparent substances like air or water. The lines that are used to show the path of light are called **rays**. You cannot see a single light ray. A stream of light rays is called a **beam**. A beam of light will contain countless individual waves usually with a range of energies.

non-luminous objects that release no visible light of their own

luminous object that releases its own light

rays narrow beams of light

beam a wide stream of light rays, all moving in the same direction

FIGURE 9.43 Beams of light can be seen in fog.

By knowing how to guide a beam of light we can make a huge array of optical devices from the simple mirror to the Hubble Space Telescope.

Seeing beams of light

You can see beams of light only when particles in substances like air scatter the light as shown in the photograph in figure 9.43. Some of the scattered light enters your eye, allowing you to see the particles within the beam.

A beam of light can be seen if there is smoke or fog in the air. Light is scattered by the tiny particles. Some of the scattered light enters your eye, allowing you to see the particles within the beam.

SCIENCE AS A HUMAN ENDEAVOUR: Computer graphics

Modern computers can calculate the paths of millions of light rays from the simulated light sources in computer games. Game engines require the programmers to have an extensive understanding of the physics of light so that reflection, refraction and scattering can be taken into account to produce realistic surfaces, water effects and atmospheric effects.
The most difficult challenge is to reproduce the way faces reflect light in multiple ways at different depths of the skin. When a face looks nearly real, but not quite, it is said to fall into the 'uncanny valley'. Even with the best graphics available this often produces an unrealistic look — for now.

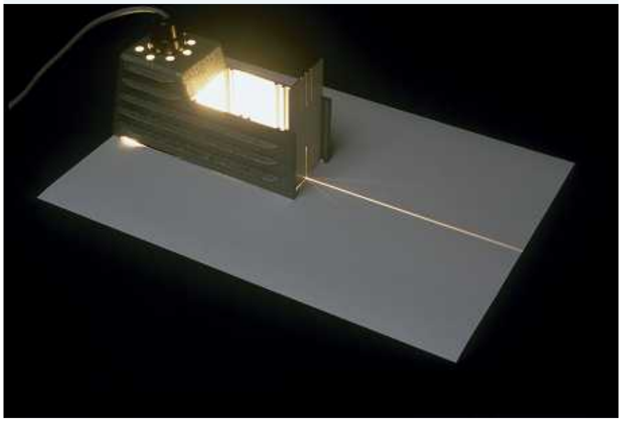
FIGURE 9.44 A face that looks nearly real, but not quite

Ray boxes

The ray box shown in figure 9.45 provides a way of tracing the path of light. It contains a light source and a lens that can be moved to produce a wide beam of light that spreads out, converges or has parallel edges. The light box is placed on a sheet of white paper, making the beam visible as some of the light is reflected from the paper into your eyes.

Black plastic slides can be placed in front of the source to produce a single thin beam or several thin beams. The beams are narrow enough to trace with a fine pencil onto the white paper. The fine pencil line can be used to represent a single ray.

FIGURE 9.45 A ray box provides a way of tracing the path of light.



9.9.3 Light interacting with matter

When light meets a boundary between two different substances, as we have seen above, a number of things can happen.

On the rebound

The light may bounce off the surface of the substance. This is called **reflection**, and is what allows you to see non-luminous objects. Light can also be reflected from particles within substances. This is called **scattering** because the light bounces off in so many different directions. Light is scattered by the particles of fog, dust and smoke in the atmosphere. Scattering is also evident in cloudy water. A luminous object in very deep or dirty water is not visible from the surface because all of the light is scattered before it can emerge. The same object is more likely to be visible on the surface of shallower or cleaner water because less light would be scattered.

Just passing through

The light may travel through the substance. Some light is always reflected when light crosses a boundary between two substances. If most of the light travels through the substance, the surface is called **transparent** because enough light gets through for you to be able to see objects clearly on the other side (figure 9.46a). Some materials let just enough light through to enable you to detect objects on the other side, but scatter so much light that you can't see them clearly. The frosted glass used in some shower screens is an example. Such materials are said to be **translucent** (figure 9.46b).

Lost inside

The light may be absorbed, transferring its energy to the particles in the substance. Substances that absorb or reflect all the light striking them are said to be opaque. Most objects in your classroom are **opaque** (figure 9.46c).

reflection bouncing off the surface of a substance

scattering light sent in many directions by small particles within a substance

transparent a substance that allows most light to pass through it. Objects can be seen clearly through transparent substances.

translucent allowing light to come through imperfectly, as in frosted glass.

opaque a substance that does not allow any light to pass through it

FIGURE 9.46 a. Transparent b. translucent c. opaque materials

9.9.4 Reflections

When you look in a mirror you see an image of yourself. If the mirror is a plane or flat mirror, the image will be very much like the real you. If the mirror is curved, the image might be quite strange.

The images in mirrors are formed when light is reflected from a very smooth, shiny metal surface behind a sheet of glass. Early mirrors were polished metal. If you were poor, a faint image could also be formed when light is reflected from other smooth surfaces, such as a bucket of water.

Why can't you see your image in a wall?

When you look very closely at surfaces like walls, you can see that they are not as smooth as the surface of a mirror. The laws of reflection are still obeyed, but light is reflected from those surfaces in all directions. It doesn't all appear to be coming from a single point. There is no image.

9.9.5 Using mirrors

Whenever light is reflected from a smooth, flat surface, it bounces away from the surface at the same angle from which it came. More scientifically we say *that the angle of incidence equals the angle of reflection*. This observation is known as the **Law of Reflection**. This law can be used to find out where your image is when you look into a mirror.

Figure 9.47 shows how the Law of Reflection works. To help us measure angles correctly, we draw an imaginary line at right angles to the surface of the mirror. We call this the **normal**. Note that we measure the **angle of incidence** from the **incident ray** to the normal NOT to the surface of the mirror. We measure the **angle of reflection** from the **reflected ray** to the normal also.

Almost all of the light coming from the object and striking the mirror is reflected. (A very small amount of light is absorbed by the mirror.) All of the reflected light appears to be coming from the same point behind the mirror; and that is exactly where the image is. The image is the same distance behind the mirror as the object is in front of the mirror and it is the same size. However, it is also flipped side to side, or, laterally inverted.

Law of Reflection the angle of incidence must equal the angle of reflection

normal is a line drawn perpendicular to a surface at the point where a light ray meets it

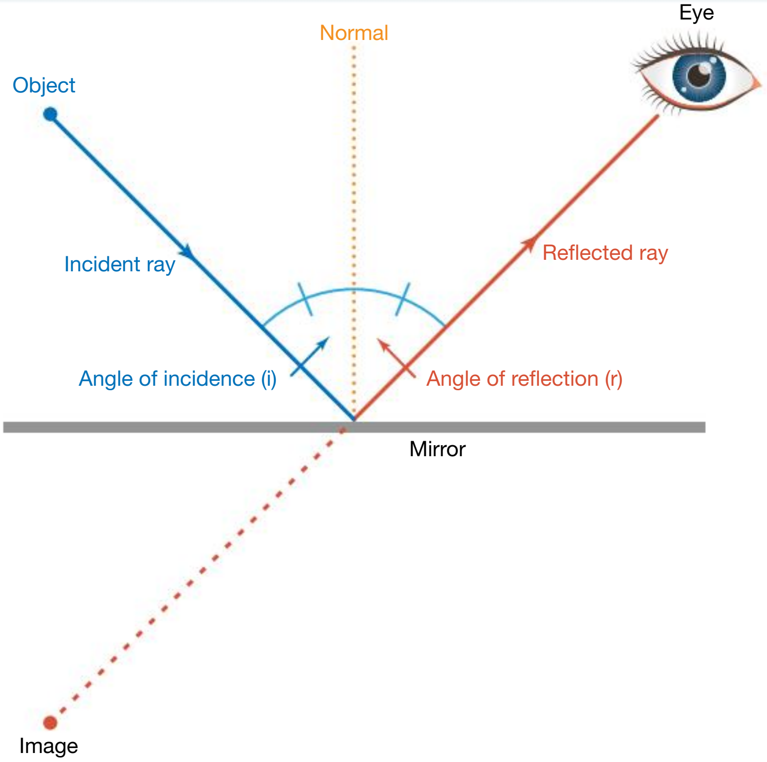
angle of incidence the angle between an incident ray on a surface and the line perpendicular to the surface at the point of incidence, called the normal

incident ray the ray that approaches the mirror

angle of reflection the angle measured from the reflected ray to the normal

reflected ray the ray that leaves the surface of the mirror

FIGURE 9.47 The reflected light appears to be coming from just one place. The image seems to be behind the mirror.



The Law of Reflection: the angle of incidence equals the angle of reflection.

Lateral inversion

The sideways reversal of images that you see when you look at yourself in a mirror is called **lateral inversion**. The sign on the ambulance in the photograph on the right is printed so that drivers in front of it can easily read the word 'AMBULANCE' in their rear-view mirrors.

FIGURE 9.48 Why is the word 'AMBULANCE' printed in reverse?

Reflection from curved mirrors

Curved mirrors may be **concave** (curved inwards) or **convex** (curved outwards). Light reflecting from concave and convex mirrors also follows the Law of Reflection, such that the parallel rays of light are reflected to a **focal point** as shown in figure 9.49.

Images in convex mirrors are upright but distorted and smaller. They can reflect light from a wide range of angles. This means they are useful as security mirrors in shops or as wing mirrors on cars.

Images in concave mirrors are usually upside down until you get closer when they give a magnified image. This makes them useful as shaving or make-up mirrors. They can also be used to redirect light forward in a beam, as in a torch or headlights.

lateral inversion reversed sideways
concave curved inwards
convex curved outwards
focal point the focus for a beam of light rays

FIGURE 9.49 Reflection of light from convex and concave mirrors

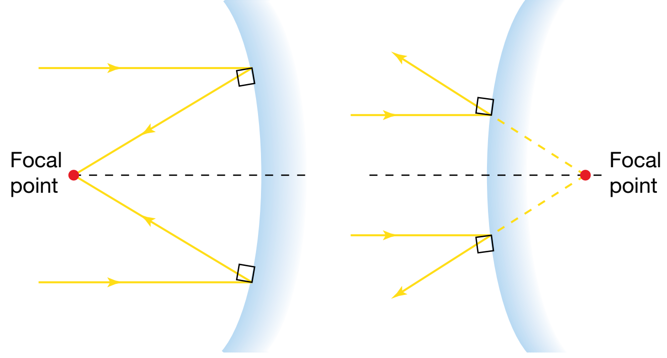


FIGURE 9.50 Uses of convex and concave mirrors

on Resources

eWorkbooks Reflection and scattering of light (ewbk-3847)
Curved mirrors (ewbk-3849)

elog-0286

INVESTIGATION 9.7

Looking at images

Aim

To observe and compare the reflection of light from plane mirrors and curved mirrors

Materials

- plane mirror
- shiny tablespoon or soup spoon

Method

1. Look at your image in the back of a spoon. This surface is **convex**. Convex means curved outward. Move the spoon as close to your eyes as you can and then further away. Is the image small or large? Right-side up or upside down? Is there anything strange about the image? Record your observations in a table like the one provided.
2. Look at your image in the front of the spoon. This surface is **concave**. Concave means curved inward. Move the spoon closer to you and then further away. Record your observations in the table.

3. Look at the image of your face in a plane mirror. Wink your right eye and take notice of which eye appears to wink in the image.
4. Write the word IMAGE on a piece of paper and place it in front of the mirror so that it faces the mirror. Write down the word as you see it in the image.
5. Write down how you think an image of the word REFLECTION would look in the mirror. Test your hypothesis about the image of the word REFLECTION.

Results

TABLE Observations using convex and concave mirrors

	Observations of image		
	First observation	When you move closer	When you move further away
Convex side			
Concave side			

Discussion

1. Which eye in the plane mirror image appears to wink?
2. Which letters in the image of the word IMAGE look different? Which look the same?
3. Was your hypothesis about the word REFLECTION correct?
4. List some places where you have seen curved mirrors. State whether the mirrors were convex or concave and explain why they are used.

Conclusion

What can you conclude about the reflection of light in plane compared to curved mirrors?

9.9.6 Refraction

When a wave enters a region where it meets resistance it will slow down. The waves will 'bunch up' and the wavelength will decrease. This will happen to water waves as they approach the beach, sound waves slow down when moving into cooler air and light waves slow down below the speed of light in transparent and translucent substances.

When the light hits the new substance head on, the beam slows down but stays in a straight line. Things change when the light hits the new substance at an angle. Here one side of the beam slows down before the other. The effect of this is that the beam changes direction. This is *refraction*.

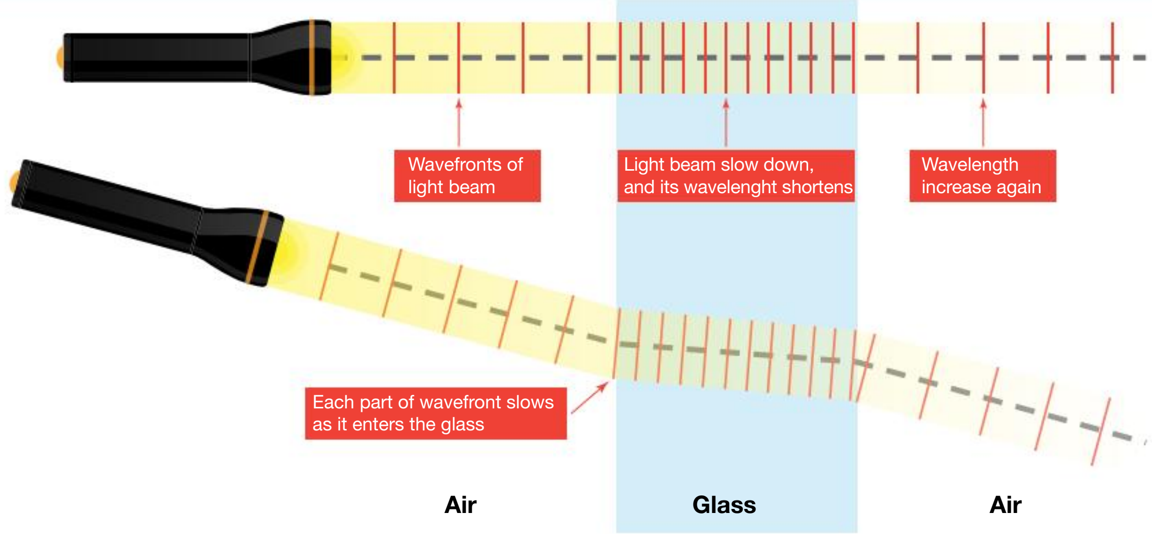
To describe the change in direction, we measure the angles between the light beam or ray and the normal.

- When a beam enters the glass it will refract *towards* the normal.
- When the beam leaves the glass it will move *away from* the normal.

Refraction effects

Water can make a bowl of water, a swimming pool or any body of clear water appear shallower than it is. Light leaving the surface of the water changes direction. The eye sees the light appearing to travel in a straight line. This gives the illusion that the water is not as deep as it is. Objects that are part in the water and part out can appear broken from some angles, as the light travelling through the water will enter your eyes from a different angle to the light from the part of the object sticking out of the water.

FIGURE 9.51 The wavefront is a line connecting the crests of the waves in the beam that were emitted at the same time. The wavelength is the distance between wavefronts. The wavefronts 'bunch up' in the glass because the wave slows down.



int-0673

FIGURE 9.52 A ray of light will refract towards the normal when it enters a substance that slows the light.

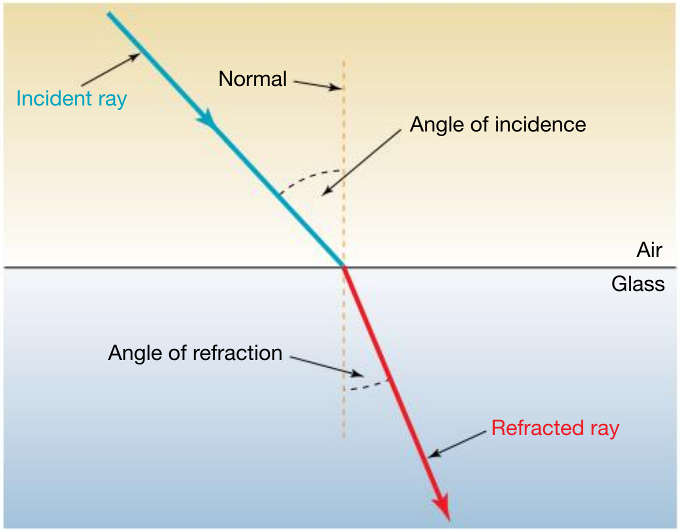
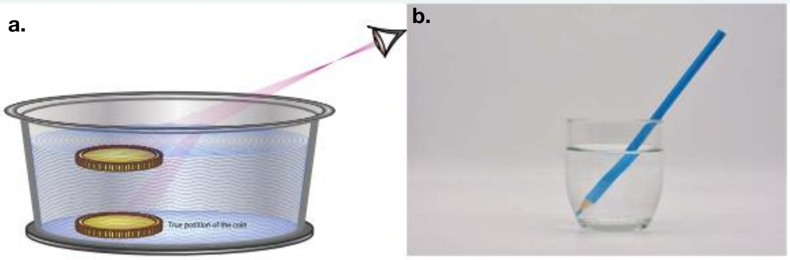


FIGURE 9.53 a. The coin appears to be higher in the water than it is due to refraction. b. The pencil appears broken due to refraction.



Resources

eWorkbook Refraction (ewbk-3851)
Video eLesson Twinkle twinkle (eles-0071)

elog-0288

INVESTIGATION 9.8

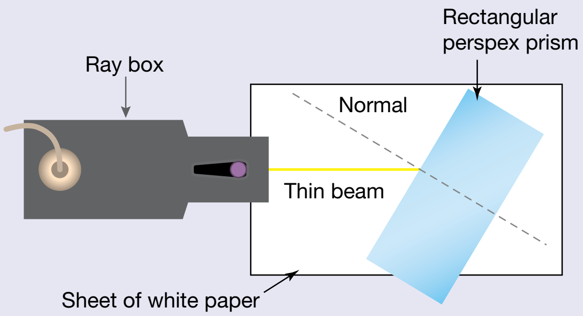
How much does it bend?

Aim

To investigate the refraction of light as it travels into and out of a rectangular prism

Materials

- ray box kit
- power supply
- sheet of white paper



Method

Connect the ray box to the power supply. Place a sheet of white paper in front of the ray box. Project a single thin beam of white light towards a rectangular perspex prism as shown in the diagram.

Results

1. Does the light bend towards or away from the normal as it enters the perspex? (Remember that the normal is a line that can be drawn at right angles to the boundary. It is shown as a dotted line in the diagram. You don't need to draw it — just imagine that it's there.)
2. Imagine a normal at the boundary where the light leaves the perspex to go back into the air. Which way does the light bend as it re-enters the air — towards or away from the normal?
3. Does all of the light travelling through the perspex re-enter the air? If not, what happens to it?
4. Look at the light beam as it enters and leaves the perspex. What do you notice about the direction of the incoming and emerging beam?
5. Turn the prism without moving the ray box so that the light enters the perspex at different angles.
   a. How can you make the incoming light bend less when it enters the perspex?
   b. How can you make the incoming light bend more when it enters the perspex?

Conclusion

How does light behave when it travels through air and through perspex?

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INVESTIGATION 9.9

Floating coins

Aim

To observe the refraction of light

Materials

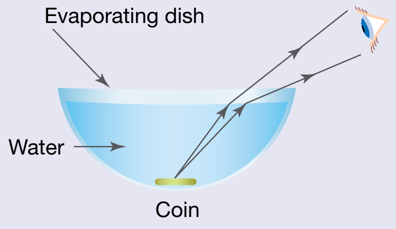
- 2 beakers
- evaporating dish
- coin

Method

Place a coin in the centre of an evaporating dish and move back just far enough so you can no longer see the coin. Remain in this position while your partner slowly adds water to the dish.

Results

1. Make a copy of the diagram shown. Use dotted lines to trace back the rays shown entering the observer's eye to see where they seem to be coming from. This enables you to locate the centre of the image of the coin.
2. Is the image of the coin above or below the actual coin?
3. What appears to happen to the coin while water is added to the evaporating dish?



Conclusion

What can you conclude about the behaviour of light through air and through water?

9.9.7 Refraction and lenses

Lenses are usually made of glass or plastic. When light passes through them it slows down as usual and bends. The slowing down is refraction. Due to their special shapes, the light can be guided to a point where it may be projected on a screen.

A common shape of lens is **biconvex** (convex lens) — that means it is curved outwards on both sides. A beam of parallel rays of light travelling through a biconvex lens 'closes in' (converges) towards a point called the focal point, or focus.

Another type of lens is a **diverging lens** (concave lens), which spreads light outwards because of its biconcave shape. A biconcave lens does not have a real focal point. When the parallel light rays emerge from a biconcave lens, they do not converge to a focal point. However, if you trace the rays back to where they are coming from, you find that they do appear to be coming from a single point. That point is called the **virtual focal point**, or virtual focus.

biconvex a convex lens with both sides curved outwards
diverging lens lens that bend rays so that they spread out. Diverging lenses are thinner in the middle than at the edges.
virtual focal point a common point from which rays appear to have come before passing through a concave lens

FIGURE 9.54 a. Biconvex lenses converge light on a focal point. **b.** Biconcave lenses spread light outwards.

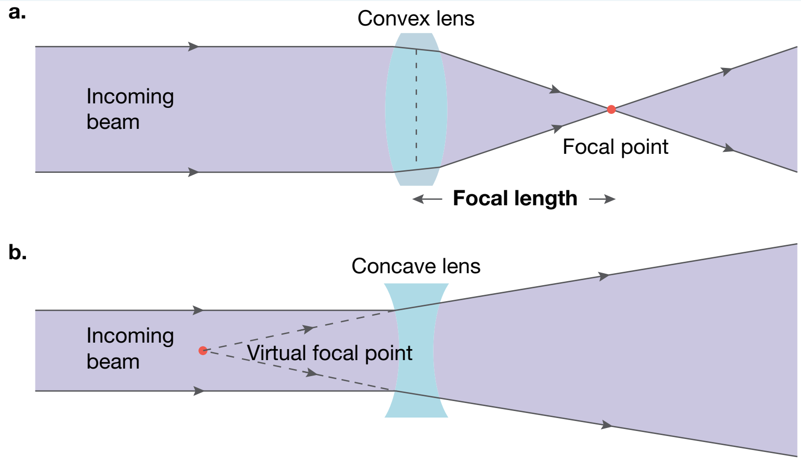
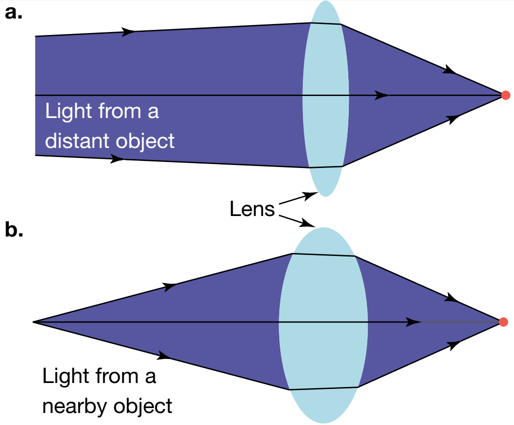


FIGURE 9.55 a. The light coming from a nearby object needs to be bent more than the light coming from a distant object. **b.** The lens in your eye becomes thicker when you look at nearby objects.



on Resources

- **Video eLesson** Galileo and the telescope (eles-1765)
- **Interactivity** Lenses (int-1017)

elog-0292

INVESTIGATION 9.10

Seeing the light

Aim

To investigate the reflection of light and its transmission through a prism and lens

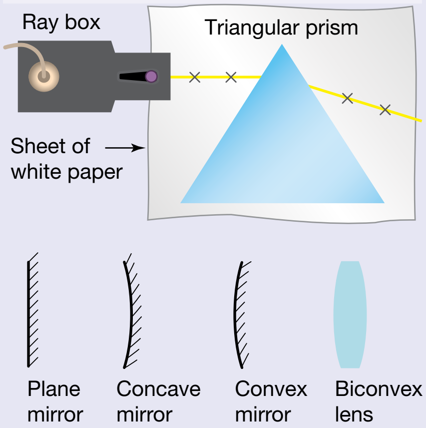
Materials

- ray box kit
- power supply
- several sheets of white paper
- ruler and fine pencil

Method

1. Connect the ray box to the power supply. Place a sheet of white paper in front of the ray box. Move the lens backwards and forwards until a beam of light with parallel edges is projected.
2. Use one of the black plastic slides to produce a single thin beam of light that is clearly visible on the white paper.
3. Trace the path of this single beam of light as it meets the lens, prism or one of the mirrors shown in the diagram provided. The path can be traced by using pairs of very small crosses along the centre of the beam before and after meeting each 'obstacle'. Trace and label the shape of each 'obstacle' before you trace the light paths.
4. Change the slide in the ray box so that you can project several parallel beams towards each of the 'obstacles'.
5. Use a ruler to draw a small diagram showing the path followed by the parallel beams when they meet each of the 'obstacles'.

Tracing the path of a beam of light



Results

1. Record the path of the single beam of light.
2. Record the path of the parallel beams of light.

Discussion

1. What happens to a beam of light when it meets a perspex surface:
   a. 'head on'
   b. at an angle?
2. What happens to a beam of light when it meets a plane mirror surface:
   a. 'head on'
   b. at an angle?
3. Describe your observations of the path followed by the three parallel beams when they meet each of the mirrors and the lens.

Conclusion

What can you conclude about the behaviour of light in this investigation?

elog-0294

INVESTIGATION 9.11

Focusing on light

Aim

To investigate the transmission of light through different lenses

Materials

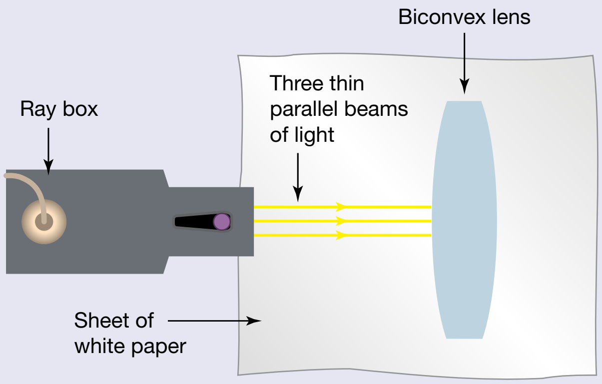
- ray box kit
- sheet of white paper
- 12 V DC power supply
- ruler and fine pencil

Method

1. Connect the ray box to the power supply and place it on a page of your notebook.

Part A: Biconvex lenses

2. Place the thinner of the two biconvex lenses in the kit on the page and trace out its shape. Project three thin parallel beams of white light towards the lens.
3. Trace the paths of the light rays as they enter and emerge from the lens. Remove the lens from the paper so that you can draw the paths of the light rays through the lens.
4. Replace the thin biconvex lens with a thicker one and repeat the previous steps.



Part B: Biconcave lenses

5. Place the thinner of the two biconcave lenses on your notebook page and trace out its shape.
6. Trace the path of each of the three thin light beams as they enter and emerge from the lens. Remove the lens from the page so that you can draw the paths of the light beams through the lens.

Results

Part A: Biconvex lenses

Record the paths of the beams of light through the biconvex lens.

Part B: Biconcave lenses

Record the paths of the beams of light through the biconcave lens.

Discussion

1. State the focal length (distance from the focal point to the centre of the lens) for each lens.
2. Which of the biconvex lenses bends light more, the thin one or the thicker one?
3. Explain why the middle light ray does not bend.
4. How many times do each of the other rays bend before arriving at the focal point?
5. Do the diverging rays come to a focus?
6. Do the diverging rays appear to be coming from the same direction? Use dotted lines on your diagram to check.
7. Predict where the diverging rays will appear to come from if you use a thicker biconcave lens. Check your prediction with the thicker biconcave lens in the ray box kit.

Conclusion

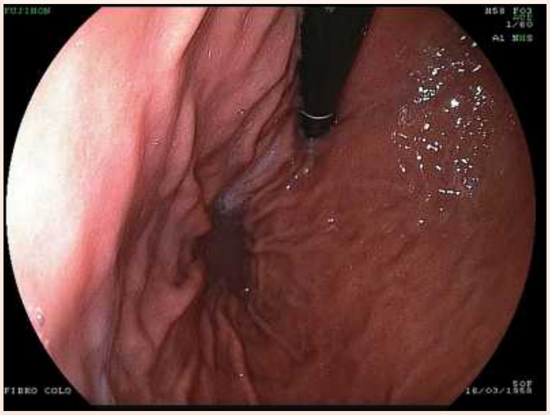
What can you conclude about the behaviour of light through biconvex and biconcave lenses?

9.9.8 Piping light

SCIENCE AS A HUMAN ENDEAVOUR: Piping light for use in medicine

The photograph in figure 9.56 shows the inside of a human stomach. It has been photographed through a long, flexible tube called an **endoscope**. Inside the endoscope are two bundles of narrow glass strands called **optical fibres**. The glass in optical fibres is made so that light is unable to emerge from the glass.

FIGURE 9.56 Optical fibres allow us to see inside the human body via an endoscope.



A beam of bright light is directed through one bundle of fibres, illuminating the inside of the stomach. Some of the light is reflected through the other bundle of fibres. A lens at the end of this bundle allows an image to be viewed, photographed or videotaped.

Endoscopes can be used to look at many different parts of the body. Different types of endoscopes include:

- gastroscopes, which are used to examine the stomach and other parts of the digestive system
- arthroscopes, which are used to search for problems in joints like shoulders and knees
- bronchoscopes, which are used to see inside the lungs.

Endoscopes can also be used in laser surgery. Intense laser beams can be directed into the optical fibres. The heat of the laser beams can be used to seal broken blood vessels or destroy abnormal tissue inside the body.

The glass in optical fibres is made so that light is unable to emerge from the glass. As light travels from a substance such as glass into air, it bends away from the normal. As the incident angle gets larger, the light bends more and more. Eventually the angle becomes so great that the incident light just can't bend any more. This angle is called the **critical angle**. When it is reached the light doesn't emerge from the glass, it will just travel along the boundary.

If the light hits the boundary at an angle greater than the critical angle, instead of leaving the glass, it is reflected back into it. This process is called **total internal reflection**. Figure 9.58 shows how total internal reflection occurs in an optical fibre.

endoscope a long, flexible tube with one optical fibre to carry light to an area inside the body and another optical fibre to carry light from the body to a lens. The image formed by the lens is examined or recorded.

optical fibres narrow strands made of two concentric glass layers so that the light is internally reflected along the fibres

critical angle when the incident angle becomes so great that the incident light can't bend any more

total internal reflection the complete reflection of a light beam that may occur when the angle between a boundary and a beam of light is small

FIGURE 9.57 A bundle of optical fibres. The light can be seen through the ends.

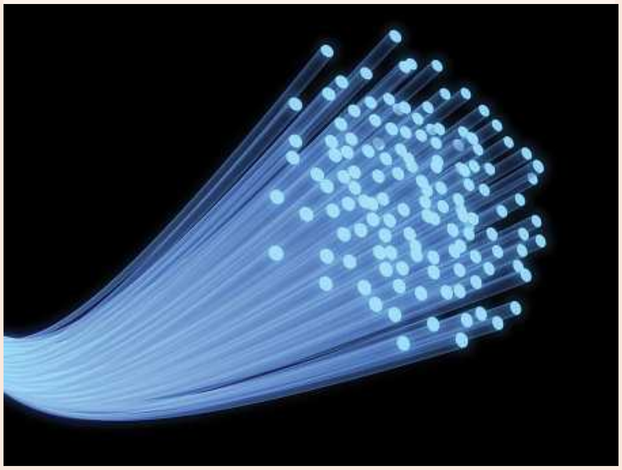
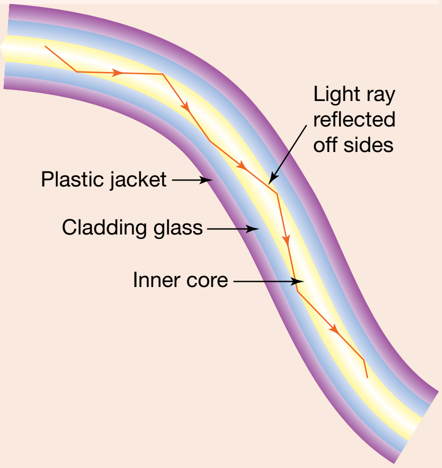


FIGURE 9.58 Total internal reflection in an optical fibre



on Resources

Video eLesson Light pipes (eles-1087)

elog-0296

INVESTIGATION 9.12

Total internal reflection

Aim

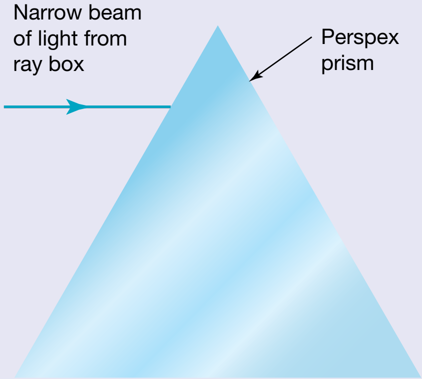
To investigate total internal reflection in a triangular prism

Materials

- ray box kit
- 12 V DC power supply
- perspex triangular prism

Method

1. Connect the ray box to the power supply. Place the ray box over a page of your notebook. Use one of the black plastic slides in the ray box kit to produce a single thin beam of light that is clearly visible on the white paper.
2. Place a perspex triangular prism on your notebook and direct the thin beam of light towards it as shown in the diagram provided. Observe the beam as it passes through the prism.
3. Turn the prism slightly anticlockwise, closely observing the thin light beam as it travels from the perspex prism back into the air. Continue to turn the prism until the beam no longer emerges from the prism.



Results

1. Describe what happens to the thin light beam as it passes from air into the perspex prism and back into the air.
2. What happens to the beam of light when it no longer emerges from the prism?

Discussion

1. Draw a series of two or three diagrams showing how the path taken by the beam of light changed as you turned the prism.
2. Explain how the amount of light reflected changes as the prism is turned.

Conclusion

What can you conclude about the behaviour of light within a perspex prism?

elog-0298

INVESTIGATION 9.13

Optical fibres

Aim

To model the transmission of light through an optic fibre

Materials

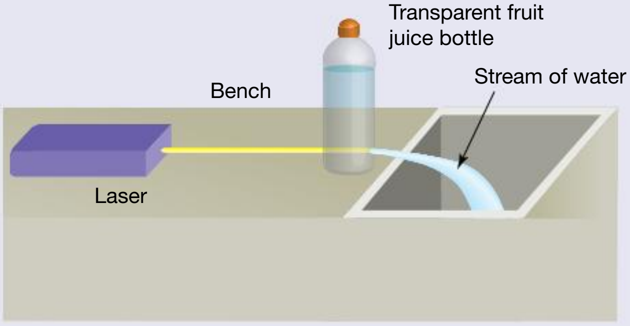
- transparent 2–3 L fruit juice container
- large nail
- laser (class 1)
- demonstration optical fibre cable or light pipe

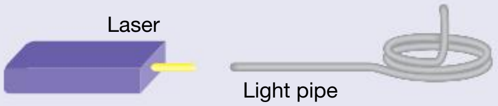
CAUTION

Class 1 and class 2 lasers have a relatively low power output and so are safe for classroom use under direct supervision of the teacher. Laser beams should not be pointed towards others in the room because of the sensitivity of the retina of the eye. Ensure that those viewing this demonstration are positioned on either side of the stream of water to eliminate the possibility of the laser beam being directed towards them.

Method

1. Use the nail to poke a narrow 5 mm hole into the front of a fruit juice container, approximately 5 cm from the bottom.
2. Darken the room.
3. Fill the container to the top with water and position it on the edge of a sink so that a thin stream of water flows from the container into the sink.
4. Direct a laser beam into the container and out through the centre of the stream of water.
5. Shine a laser beam down a length of 'light pipe' or loop of optical fibre.





Results

1. Describe the path of the laser beam through the stream of water.
2. Describe the laser beam down the length of optical fibre cable or light pipe.

Discussion

1. Explain why the laser beam took the path of light observed in these demonstrations.
2. Compare the speed of light in air to that in water or the material making up the optical fibre core.
3. Explain how these demonstrations rely on the difference in the speed of light through these media.

Conclusion

What can you conclude about the transmission of light through different media?

EXTENSION: Why diamonds sparkle

Diamonds can sparkle with coloured light, each of its surfaces producing a dazzling display. Diamond is the most optically dense, naturally occurring material on Earth. This means that light entering a diamond through each of its facets (or geometrically cut sides) is refracted by a huge angle, causing light inside the gemstone to bounce back and forth several times before it strikes a facet with an angle straight enough to escape. Because the light has travelled so far, the spectrum of colours that make up light have dispersed (or separated) so significantly that a stunning display of colours is produced.

Resources

assessON Additional automatically marked question sets

9.9 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. MC You cannot usually see light as it travels through the air. What makes it possible to see a beam of light?
   A. When particles in the air scatter the light
   B. When the beam is very bright
   C. When the beam contrasts well with the background
   D. When the light waves have a very long wavelength
2. What happens to light when it travels through air and meets:
   a. a transparent surface
   b. a translucent surface
   c. an opaque surface?
3. What will the angle of reflection be in each of these cases?
   a. The angle of incidence is 35°.
   b. The angle between the reflected ray and the mirror is 40°.
   c. The angle between the incident ray and the mirror is 20°.
4. In which type of mirror can your image be:
   a. upside down
   b. magnified
   c. the right way up, unmagnified and laterally inverted?
5. Sketch the word LIGHT but laterally inverted.
6. When a beam of light enters a denser medium (for example, from air into water) will the following properties of the beam increase, decrease or stay the same?
   a. Wavelength
   b. Speed
   c. Frequency
   d. Angle between the ray and the normal

Apply and analyse

7. The illustration shows a ray of light emerging from still water after it has been reflected from a fish. Should the spear be aimed in front of or behind the image of the fish? Use a diagram to explain why.

8. Are photons particles or waves? Explain your answer.
9. Name and sketch the shape of a lens that:
   a. converges a beam of light to a single point
   b. makes the rays in a beam of light diverge.
10. MC What is the focal length of a converging lens a measure of?
   A. How long the image will be
   B. The distance between the focus (the point to which parallel rays of light converge) and the lens
   C. The distance between the object and the image
   D. The distance you must place the object at to form an image.
11. Explain why the focal point of a diverging lens is called a virtual focal point.
12. Explain how optical fibres allow light to travel along a bent tube.
13. Explain how an endoscope works, listing three medical uses.
14. Can total internal reflection occur when light travels from air into glass? Explain your answer.

Evaluate and create

15. SIS You are presented with three different transparent materials and you are asked to determine which of them slows light down the most. Plan an experiment stating the independent, dependant and controlled variables that you would use. State the equipment that you would use to make any measurements. Explain how your readings could determine which substance slowed light down the most.

Fully worked solutions and sample responses are available in your digital formats.

9.10 Seeing the light

LEARNING INTENTION

At the end of this subtopic you will be able to describe how the eye focusses an image on the retina and how this process can go wrong. You will also be able to explain how our display technology uses only three colours to produce full-colour images.

9.10.1 The eye

Everything that you see is an image, created when the energy of light waves entering your eyes is transmitted to a 'screen' at the back of each eye.

This screen, called the **retina**, is lined with millions of cells that are sensitive to light. These cells respond to light by sending electrical signals to your brain through the **optic nerve**.

FIGURE 9.59 The human eye

Some of the light reflected from your surroundings, along with light emitted from luminous objects such as the Sun, enters your eye. It is refracted as it passes through the outer surface of your eye. This transparent outer surface, called the **cornea**, is curved so that the light converges towards the **lens**. Most of the bending of light done by the eye occurs at the cornea.

On its way to the lens, the light travels through a hole in the coloured **iris** called the **pupil**. The iris is a ring of muscle that controls the amount of light entering the lens. In a dark room the iris contracts to allow as much of the available light as possible through the pupil. In bright sunlight the iris relaxes, making the pupil small to prevent too much light from entering. The clear, jelly-like lens bends the light further, ensuring that the image formed on the retina is sharp.

retina the curved surface at the back of the eye. It is lined with sight receptors.

optic nerve a large nerve that sends signals to the brain from the sight receptors in the retina

cornea the curved, clear outer covering of your eye

lens a transparent, curved object that bends light towards or away from a point called the focus. The eye has a jelly-like lens.

iris the coloured part of the eye that opens and closes the pupil to control the amount of light that enters the eye

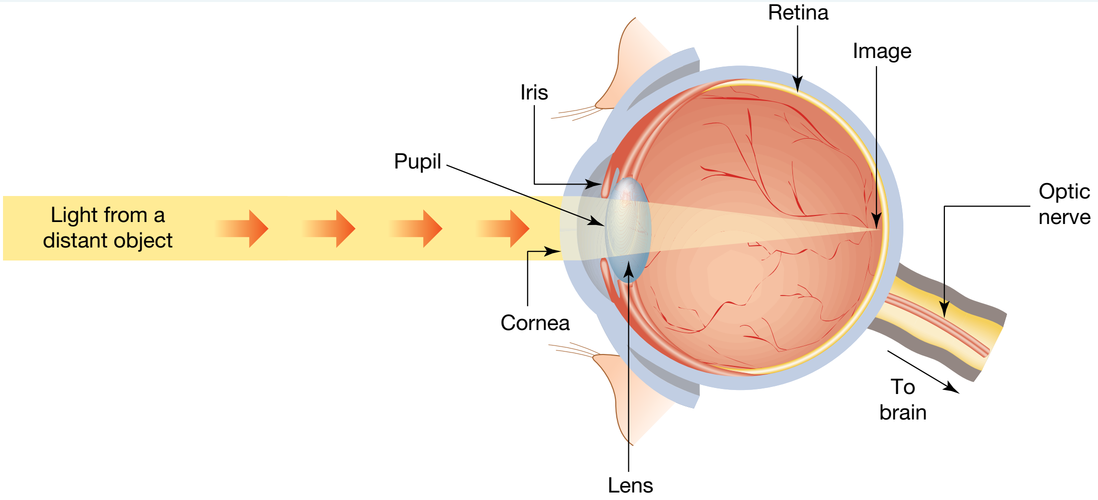
pupil a hole through which light enters the eye

ewbk-3818

eles-2635

int-8177

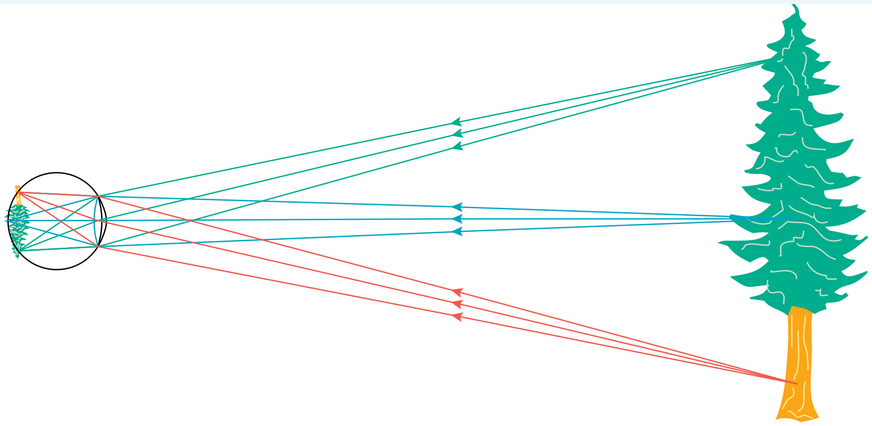
FIGURE 9.60 Side view of a human eye



Seeing upside down

The image formed on the retina is inverted. However, the brain is able to process the signals coming from the retina so that you see things the right way up.

FIGURE 9.61 The image formed on the retina is upside down.



Getting things in focus

Although most of the bending of light energy done by the eye occurs at the cornea, it is the lens that ensures the image is sharp. The lens in each of your eyes is a **converging lens**. Its shape is biconvex (see section 9.9.7).

converging lens lens that bends rays towards each other. Converging lenses are thicker in the middle than at the edges.

ciliary muscles muscles that control the shape of the lens behind the iris

accommodation changing of the lens shape to focus a sharp image on the retina according to the relative location of the cell that it has been copied to

EXTENSION: Accommodation in the eye

The exact shape of the clear jelly-like lens in your eye is controlled by muscles called the **ciliary muscles**. When you look at a distant object, the ciliary muscles are relaxed and the lens is thin, producing a sharp image on the retina. When you look at a nearby object, the light needs to be refracted more to produce a sharp image. The ciliary muscles contract and the jelly-like lens is squashed up to become thicker and stronger. This process is called **accommodation**.

The word *accommodation* comes from the Latin term *accommodatio*, meaning 'adjustment'.

on Resources

eWorkbook The eye (ewbk-3820)

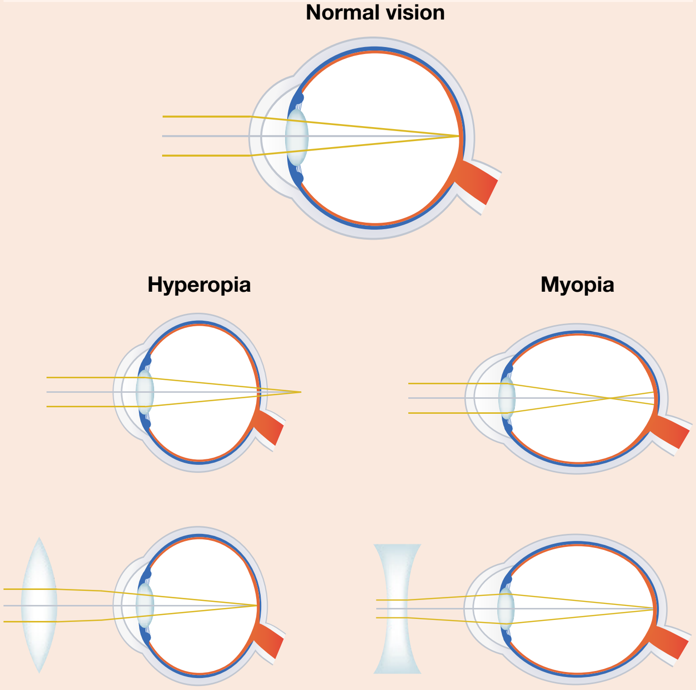
SCIENCE AS A HUMAN ENDEAVOUR: Correcting vision

Myopia: Short sightedness

Many people wear glasses or contact lenses so that they can see distant objects clearly. The condition is called **myopia**. The eyes are said to be **short sighted** as the light focuses short of, or in front of, the retina. This is caused by the lens and cornea being too strong and refracting the light rays too much, or by the eyeball being too long.

The corrective glasses or lenses are concave, and they spread the rays out before they hit your cornea. This means that the rays should now focus in the correct place.

FIGURE 9.62 Myopia is corrected with concave lenses, hyperopia is corrected with convex lenses.



Hyperopia: Long sightedness

As you get older, the tissues that make up the lens become less flexible. The lens does not change its shape as easily. Images of very close objects (like the words you are reading now) become blurred. The lens does not bulge as much as it should and the light from nearby objects converges to a point behind the retina instead of on the retina. You may have to hold what you are reading further away in order to obtain a clear image.

This change in accommodation with age is a natural process. Some people are not inconvenienced at all while others need to wear reading glasses so that they can read more easily and comfortably.

Table 9.3 shows how the shortest distance at which a clear image can be obtained changes with age. The distances shown are averages and there is a lot of variation from person to person.

TABLE 9.3 Average shortest distance at which a clear image can be obtained

Age (years)	Distance (cm)
10	7.5
20	9
30	12
40	18
50	50
60	125

myopia *see* short sighted

short sighted (myopia) the condition of not being able to see things clearly that are far away

EXTENSION: Thousands of lenses

Each human eye contains just one convex lens. Insects have compound eyes. Each eye contains many lenses. Some types of dragonfly have more than 10 000 lenses in each eye. Each eye can focus light coming from only one direction.

FIGURE 9.63
A dragonfly

elog-0300

INVESTIGATION 9.14

Getting a clear image

Aim

To investigate accommodation

Materials

ruler

Method

1. Look closely at the **X** printed here, from the smallest distance at which you can see it clearly and sharply with comfort. Quickly look away and focus on a distant object for a second or two and then focus on the 'X' again from the smaller distance. Try to feel the action of the muscles that allow you to see a sharp image of the 'X'.
2. Use the following procedure to estimate the smallest distance at which you can obtain a clear image of a nearby object. (If you are wearing glasses, remove them during this part of the experiment.)
3. Place this text vertically at arm's length from your eyes and focus on it. Move it to a position about 3 or 4 centimetres from your eyes and then gradually move the book further away until you can see the print clearly and sharply.
4. Have a partner use the ruler to estimate the distance between the text and your eyes. The ruler should be placed carefully beside your head for this measurement.

Results

1. Record the distance measured from the book to your eyes when you could see the text clearly.
2. Collate the results for the whole class and determine the average smallest distance at which a clear image could be obtained.

Discussion

1. How does your result compare with the average smallest distance for your class?
2. What was the range of results for your class? Identify possible reasons for this variation.

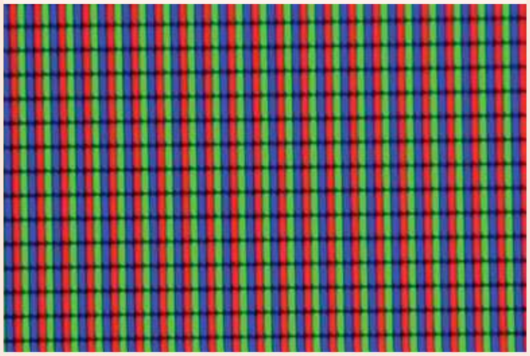
Conclusion

What can you conclude about how the human eye uses accommodation?

CASE STUDY: Seeing in three colours

Our eyes have cells in the retina that respond to red, blue and green light. Different mixes and intensities of these colours are interpreted by us as the range of colours that we can see. This is how television, computer and phone screens work. The screens are made up of many red, blue and green dots — look closely at a screen and you will only see these three colours. These are called *picture elements* or *pixels*.

FIGURE 9.64 Pixels are made of only three colours.



on Resources

assesson Additional automatically marked question sets

9.10 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. **MC** What is the name given to the shape of the lens in the human eye?
   A. Convex **B.** Concave **C.** Biconvex **D.** Biconcave
2. Which part of the human eye:
   a. does most of the bending of light occur
   b. allows light to enter the eyeball
   c. changes shape to allow more or less light into the eye
   d. carries out the process called accommodation
   e. sends messages as electrical impulses to the brain
   f. converts light detection into an electrical impulse?
3. Sketch the shape of the lens in the eye when you are viewing:
   a. a nearby object
   b. a distant object.
4. Fill in the blanks to complete the passage.
   The __________ muscles surrounding the __________ will either __________ to make the lens flatter to see more __________ objects. Or when the muscles contract, the lens edges are squashed __________ to each other, making the lens __________ in order to see __________ objects.

Apply and analyse

5. MC What happens to the speed of light as it enters the eye? (*Hint:* Refer to subtopic 9.9.)
   A. It speeds up
   B. It slows down
   C. It doesn't change
   D. It doesn't enter the eye, it is absorbed
6. Why is it common to see older people holding a newspaper at arm's length while they are reading it?
7. Why does the lens need to be thicker for viewing nearby objects?
8. SIS Use the data in the table to draw a line graph to show how the ability to focus on nearby objects changes with age.
   a. Use your graph to predict the smallest distance at which a clear image can be obtained by an average person of your age.
   b. At what age does the decrease in focusing ability appear to be most rapid?

TABLE Average focal length per age

Age (years)	Distance (cm)
10	7.5
20	9
30	12
40	18
50	50
60	125

Evaluate and create

9. SIS Research and report on the development of the bionic eye by Australian scientists. Include in your report information about:
   - macular degeneration
   - which patients it is designed to benefit
   - how it works
   - a comparison with the bionic ear.

Fully worked solutions and sample responses are available in your digital formats.

9.11 Communication

LEARNING INTENTION

In this subtopic you will explore the effect that communication had on our world. You will be able to describe AM, FM and television as radio wave transmissions and the difference between analogue and digital signals. You will understand the benefits that digital technologies bring including mobile and satellite-based communication.

9.11.1 Early communication

As you explored in 9.1.3 Science inquiry, we have come a long way in human-to-human communication — from smoke signals to writing, which was soon followed by using codes, through to email today, which also relies on codes. In this section we will explore how we use energy transmission to communicate to many people instantaneously.

9.11.2 Radio

Radio waves were discovered by Heinrich Hertz in 1887, and after a few years of clever work by the Italian engineer Guglielmo Marconi, it became possible to send messages over long distances at the speed of light.

Radio waves are emitted naturally by many objects in space from the cool gas of the interstellar medium to stars and even whole galaxies, blasting beams of radio waves across the universe. When you hear the background hiss on a radio between stations, you are hearing evidence of radio waves left over from the Big Bang itself.

Natural radio waves allow us to study the universe, but they are usually a nuisance when it comes to communication. For this we need technology to generate radio waves in a controlled fashion.

This is done by making electrons in a metal rod vibrate rapidly. This metal rod is called a **transmitting antenna** or transmitter (figure 9.65, left-hand photograph). These vibrations cause radio waves to travel through the air (at about 300 000 kilometres per second). The radio waves can be detected by a **receiving antenna** (figure 9.65, right-hand photograph), which is a metal rod just like the transmitter. The radio waves cause electrons in the receiving antenna to vibrate rapidly, producing an electrical signal.

FIGURE 9.65 Compare the sizes of these transmitting (left) and receiving (right) antennae. Why are they different?

AM radio and FM radio

Each AM and FM radio station has a particular frequency of radio waves on which it transmits sound signals.

- The sound signal must firstly be changed to an electrical signal.
- This electrical signal is called an **audio** signal.
- The waves on which messages are sent are called **carrier waves**.
- The audio signal is added to the carrier wave, producing a modulated wave, as shown in figure 9.66.
- The receiving antenna of your radio detects the modulated wave. Your radio then 'subtracts' the carrier wave from the signal, leaving just the audio signal.
- The audio signal is amplified by an audio amplifier inside the radio and sent to speakers.
- In the speakers, the changing electric current is used to make the surrounding air vibrate to produce sound.
- FM carrier frequencies are much greater than AM radio frequencies.

A comparision of AM and FM radio signals can be seen in table 9.4 and in figure 9.66.

transmitting antenna a metal structure in which vibrating electrons cause radio waves to travel through the air

receiving antenna a metal structure in which electrons are made to vibrate by radio waves or microwaves in the atmosphere

audio waves with a frequency range of sounds audible to people

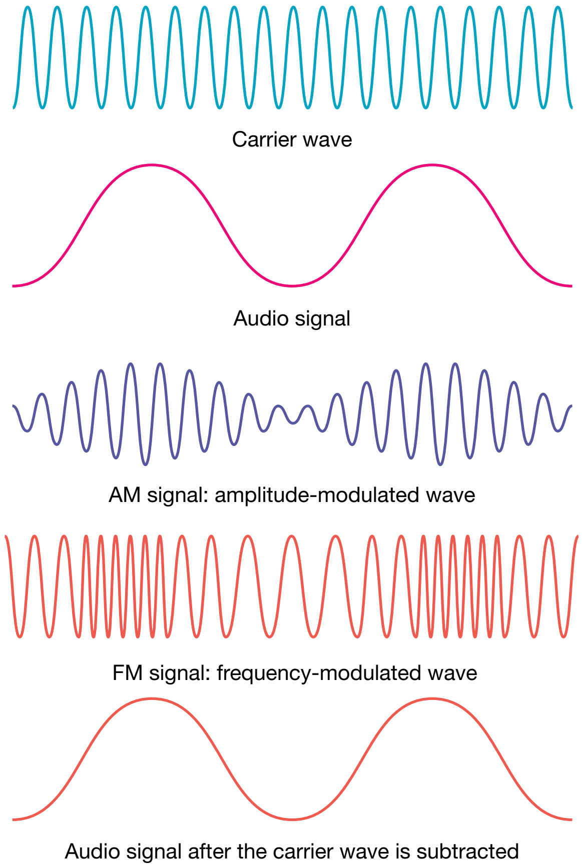
carrier waves are radio waves that are altered in a precise way so that they contain an audio signal

TABLE 9.4 Comparison of AM and FM radio

	AM	FM
Frequency kHz (kilohertz) MHz (megahertz) 1MHz = 1 000 000 Hz	540–1600 kHz	88–108 MHz
Signal transmission on carrier wave	Amplitude modulation: audio signal changes the amplitude of the carrier wave.	Frequency modulation: audio signal changes the frequency of the carrier wave.
Example	ABC Local Radio Melbourne has a carrier wave with a frequency of 774 kilohertz.	Triple J in Melbourne has a carrier wave with a frequency of 107.5 megahertz.

FM radio waves are affected less by electrical interference than AM radio waves and therefore provide a higher quality transmission of sound. However, they have a shorter range than AM waves and are less able to travel around obstacles such as hills and large buildings.

FIGURE 9.66 Comparison of AM and FM radio transmission



Digital radio

Digital radio began in 2009. Digital signals are different from AM or FM radio signals, and are discussed in section 9.11.4.

9.11.3 Television

It used to be that television signals were transmitted as radio waves on two separate carrier waves. The visual signal was added onto one carrier wave using amplitude modulation. The audio signal was carried on a separate carrier wave using frequency modulation. When you tuned your television set to a particular channel, you were selecting the visual and audio carrier waves that you wished to receive. Your television set then completed the task of removing the carrier waves and translating the signals sent into a picture and sound. This was quite a complex task, as you might imagine. Not only that, picture interference was a regular problem and due to the wide range of frequencies allocated to each channel, viewing options were limited. However, with the invention of the internet and processor power becoming cheap enough to be available for home use, the era of digital transmission of data had arrived.

Digital television commenced transmission in Australian capital cities in 2001. The phasing out of analogue signals began in 2010 and was completed in December 2014. A digital TV set-top box can be used to convert the digital signals back to an analogue form. This means that nobody had to replace their old analogue TV sets with digital TV sets unless they chose to.

9.11.4 Analogue and digital

So, what is the difference between an analogue and a digital signal?

- **Analogue** quantities are those that can have any value and can change continually over time.
- **Digital** quantities are those that can have only particular values and are represented by numbers.

Whereas analogue radio and television signals are carried as continuously changing amplitudes or frequencies, digital signals are carried as a series of 'on' and 'off' pulses. The signals can have only two values — 'on' or 'off'. The original audio and video (sound and vision) are sampled and converted into pulses. Audio signals are sampled about 40 000 times every second. Video signals are sampled more than 13 million times every second. The pulses are added to the carrier waves for transmission.

What's the advantage of digital?

Both analogue and digital television signals fade away as they travel through the air. Like all other waves, the energy they carry spreads out. So, as they travel over distance their intensity, or strength, decreases. As the continuous analogue becomes weaker, the background radiation and signals from other sources have a greater effect on the amplitude of the wave. It becomes distorted. The result is a fuzzy picture and poor-quality sound. Because digital signals can be only 'on' or 'off' pulses, background radiation and signals from other sources cannot interfere with them — even as they become weaker. The rapidly pulsating signals are still either 'on' or 'off' until the 'on' signals have faded away to nothing.

As a result, digital television has several advantages over analogue television. It provides:

- sharper images and 'ghost free' reception
- widescreen pictures
- better quality sound
- capability of 'surround' sound
- access to the internet and email
- capability of interactive television, allowing the viewer to see different camera views or even different programs on the same channel
- Electronic Program Guides (EPGs) that can provide 'now' and 'next' information about programs.

9.11.5 Using codes: Morse code and binary signals

Morse code

Before radio waves, we used optical telegraph, where flashes of light from a lantern were detected by telescope. The flashes were coded information that could be transmitted over long distances. It would be too slow to have a different code for each word so the letters were encoded as flashes. These could then build up words. This was overtaken by the electric telegraph that sent electrical signals across huge distances, making the network of telescope observation towers redundant. There were cables stretched across oceans allowing coded information from the London Stock Exchange to get to New York before their markets opened. The cost of laying a cable across the Atlantic was huge at the time, but it was seen as worth it for the more efficient, and profitable, trading that it allowed.

Morse code was a common way of encoding signals for a long time. Long and short pulses were combined to represent the letters and numbers.

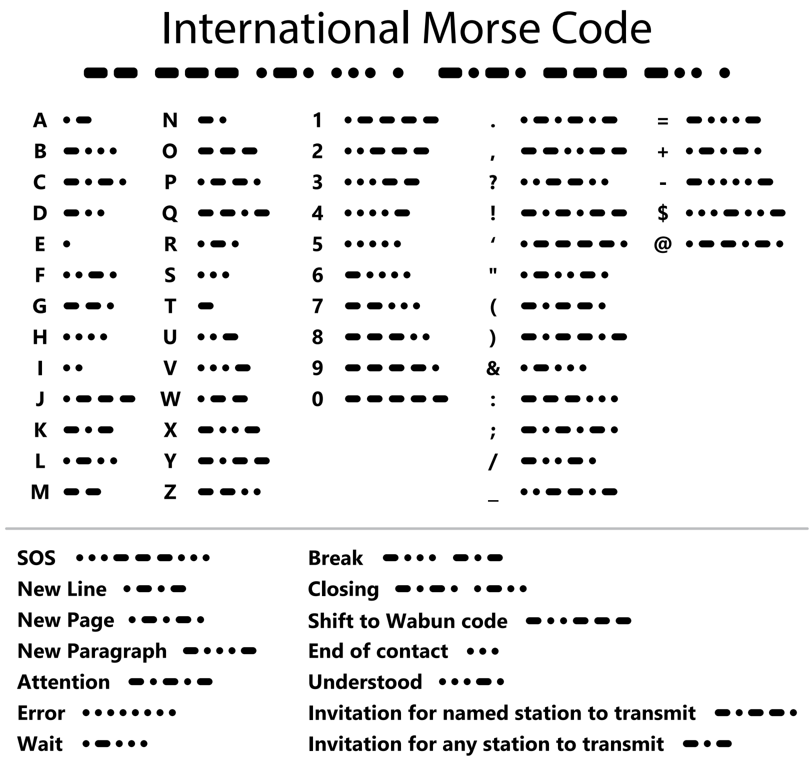
analogue quantities that can have any value and change continuously over time

digital quantities that can have only particular values and are represented by numbers

DISCUSSION

List as many technologies for human communication as you can think of. Can you put them in order of development? What science had to be discovered before these technologies could be made?

FIGURE 9.67 International Morse code showing the long and short pulses that represent the usual letters, numbers and symbols that would be used in communication.



on Resources

eWorkbook Investigating Morse code (ewbk-3822)

Binary code

In the modern era we use **binary code** to transmit information as electrical pulses in ADSL systems using the phone line, or as pulses of light if optical fibre networks are used. At a very basic level, computers use circuits that have only two states, on or off. Mathematically we represent on with a 1 and off with a zero. Using these two numbers we can represent all letters, numbers and symbols using codes similar to Morse code. Sounds can be **sampled**, broken into fast measurements of wave amplitude. These measurements are converted to numbers and the numbers send as a binary code. Pictures and video can be broken down into a string of numbers representing which pixels are on and what their colour is. Essentially, we are using the same ideas of encoding messages that we have used for thousands of years. We now transmit those codes at the speed of light, all the way around the planet and now think nothing of the huge amount of research and infrastructure building that allow us to video chat with our families and friends around the world.

binary code use of the digits 0 and 1 to represent a letter, number, or other character

sampled in the context of music, means to measure the amplitude at regular intervals in order to convert a sound into a string of numbers for digital transmission

9.11.6 Long-distance communication

Australia is covered with a network of microwave and radio repeater towers, coaxial cables, optical fibres and satellite dishes. This network allows us to transmit television and radio signals, telephone calls, facsimiles and computer data across our massive continent.

Television and radio signals, computer data and telephone messages can be transmitted over long distances using **microwaves**. Microwaves can carry many signals at the same time. However, **repeater stations** need to be used so that the signal does not fade away before it reaches its destination. Antennas on the repeater stations receive the microwave signals and send them on to the next station.

Each repeater tower needs to be within sight of the next one because microwaves, like visible light, travel in straight lines. So, the repeater towers are built on the top of hills wherever possible.

microwave an electromagnetic wave of very high frequency

repeater station retransmits communication signals with increased energy so the signal does not fade away

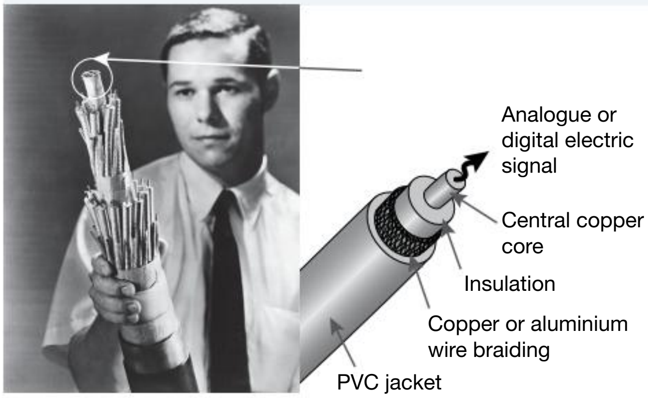
coaxial cables wires that can transmit a number of different signals as electrical pulses

The electric way

Coaxial cables allow sound, pictures and data to be transmitted as pulses of electric current rather than as electromagnetic waves. The signals are carried along conducting wires inside tubes. The thin wire is held in the centre of the tube by a plastic insulating disc. Most Australian coaxial cables contain four, six or twelve tubes. Smaller conductor wires in the cable are used to provide links to small towns along the length of the cable. They are also used to control the system. Coaxial cables are buried under the ground or laid on the ocean floor.

The first major coaxial cable in Australia was laid between Sydney, Melbourne and Canberra in 1962. Coaxial cables can simultaneously transmit many more telephone calls and television signals than earlier cables were able to. As with the microwave system, repeater stations need to be used along the length of the coaxial cable so that the signal does not fade away. Coaxial cable repeater stations need to be even closer together than microwave repeater stations.

FIGURE 9.68 A coaxial cable contains many conducting wires in up to 22 tubes. They are designed to minimise interference from outside the cable and to prevent the many signals being carried from interfering with each other.



The light fantastic

Table 9.5 shows that optical fibres can transmit more messages at one time than coaxial cable or microwaves. Electrical signals from a microphone, television camera, computer or facsimile machine are converted into pulses of light. These pulses are produced when an electrical signal is used to turn the light on and off millions of times per second.

The light pulses received at the other end are converted back into electrical signals that can be fed into speakers, a television set, computer or facsimile machine. The messages can also be retransmitted as microwaves or radio waves if necessary.

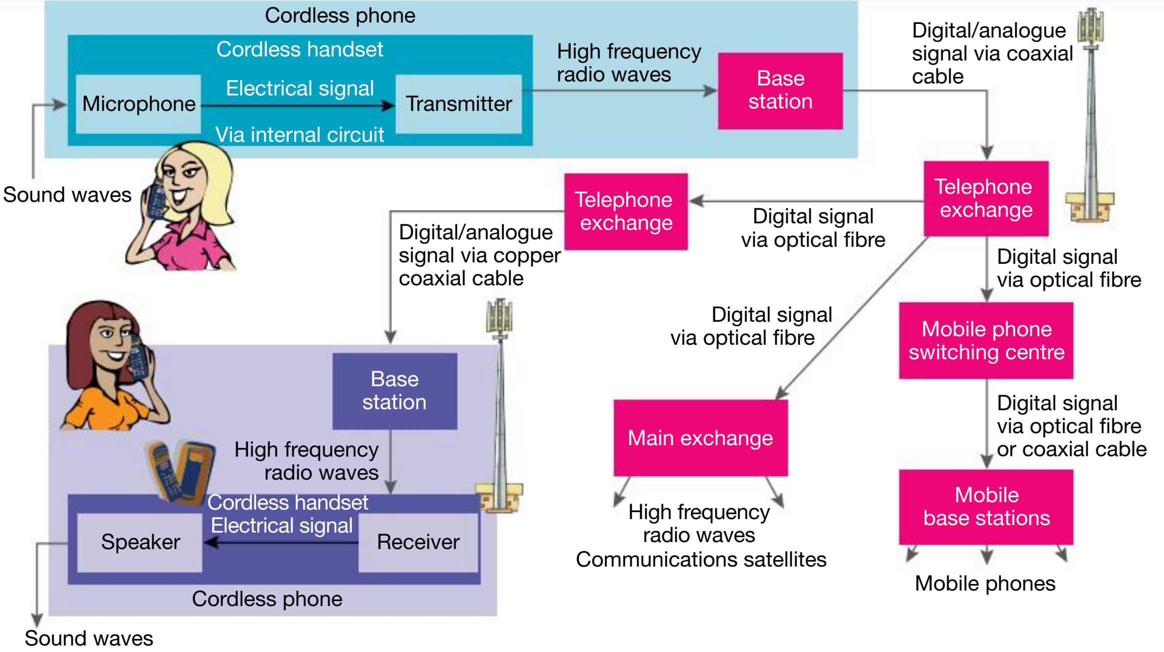
The idea of using visible light energy to transmit messages over long distances was not feasible until the invention of the laser in 1958. The word 'laser' is an acronym, standing for light amplification by stimulated emission of radiation. A laser produces an intense light beam of one pure colour. As the beam travels through the optical fibre, the glass absorbs some energy. Repeaters are needed every 35 to 55 kilometres along optical fibre cables to boost the signal. The light loses energy less quickly than normal light would, because a laser beam spreads out very little.

The first successful glass optical fibres were made in 1973. The advantages of optical fibres are so great that Australia already has a network of fibre cables between all capital cities. Optical fibres can be laid under the ground or under water. They are smaller, lighter, more flexible and cheaper than the electrical cables previously used for long-distance telephone, radio and television communication. Light pulses cannot be interfered with by radio waves, so there is no 'static'.

TABLE 9.5 Options for long-distance communication over land

Type of link	Number of two-way conversations at once
Copper cable	600
Coaxial cable	2700
Microwave	2000
Optical fibres	30 000

FIGURE 9.69 A landline is part of the communications network.



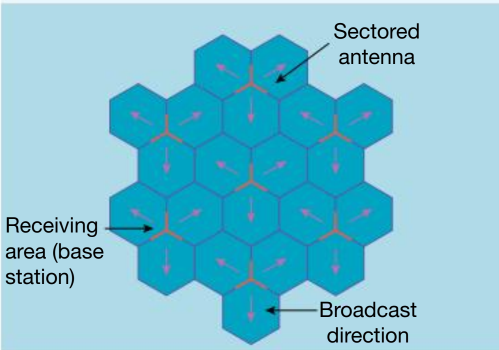
9.11.7 Mobile communication

Since the first major mobile phone service was introduced in Australia in 1987, millions of Australians have purchased mobile phones.

How mobile phones work

Your phone will break down your speech, video signal or internet communication into a digital signal that it will send as radio waves to a **base station**, which consists of several antennas at the top of a large tower or on top of a tall building. The base station is connected to a **switching centre**. Each switching centre is, in turn, connected to many base stations. The switching centre switches the call to other mobile phones through the **cellular system** or the fixed telephone system.

FIGURE 9.70 The base stations are placed at the intersection of three cells.



base station consists of antennas on top of a large tower that transmit signals from mobile phones to a switching centre

switching centres switches mobile phone calls to other base stations or to a fixed telephone system

cellular system a mobile phone system

A network of cells

Mobile phones are also called **cellular phones**. That is because the base stations are set up in a network of hexagonal cells as shown in figure 9.70. The cells range in size from 100 metres across to over 30 kilometres across. The base stations receive and transmit mobile phone signals from the cells that adjoin them. A mobile phone signal moves from cell to cell until it reaches its destination base station.

DISCUSSION

Discuss the impact on the world if all of our modern technologies were made inoperable due to a massive solar flare (an unlikely but possible scenario).

9.11.8 Satellite communication

Communications **satellites** allow radio waves and microwaves to be transmitted at the speed of light from continent to continent. In Australia, satellites are used to transmit radio, television and telephone signals from cities to remote areas.

Signals are transmitted to a communications satellite in **geostationary orbit** (figure 9.72). The signals are then sent back to other parts of Australia, or to other satellites which, in turn, transmit the signals to other continents. The energy needed to amplify and retransmit the signals is mostly provided by the Sun. Solar panels on the satellite collect solar energy, which is either used straight away or stored in batteries for later use.

cellular phones or mobile phones; so called because base stations that receive mobile phone transmissions are arranged in a network of hexagonal cells

satellite an object that orbits another object. The moon is the Earth's satellite. Scientists have made and launched many artificial satellites.

geostationary orbit describes the path of a satellite that remains above the same location of the Earth's surface

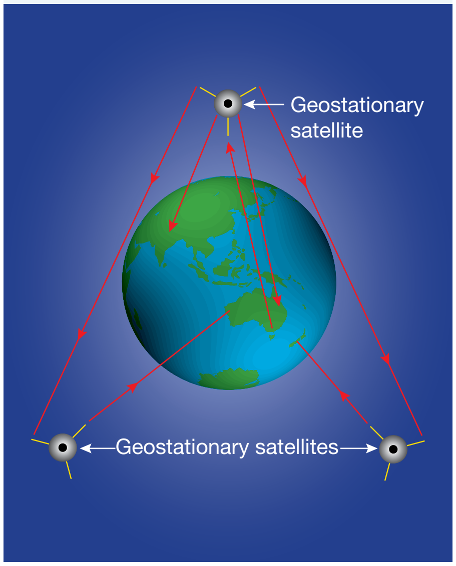
A geostationary satellite is one that orbits the Earth once every 24 hours, thus remaining over the same point on Earth at all times. In order for the satellite to orbit at that rate, it must be located about 36 000 kilometres above the equator. Tracking stations on Earth use radio signals to activate small rockets on the satellites to keep them in the correct orbit.

Dish antennas, such as the ones in figure 9.71, are aimed at a particular satellite ready to receive signals. The shape of the dish allows for the collection of a large amount of electromagnetic energy, which is focused towards the antenna.

eles-2668

FIGURE 9.71 These antennas receive signals that have been retransmitted by a geostationary satellite.

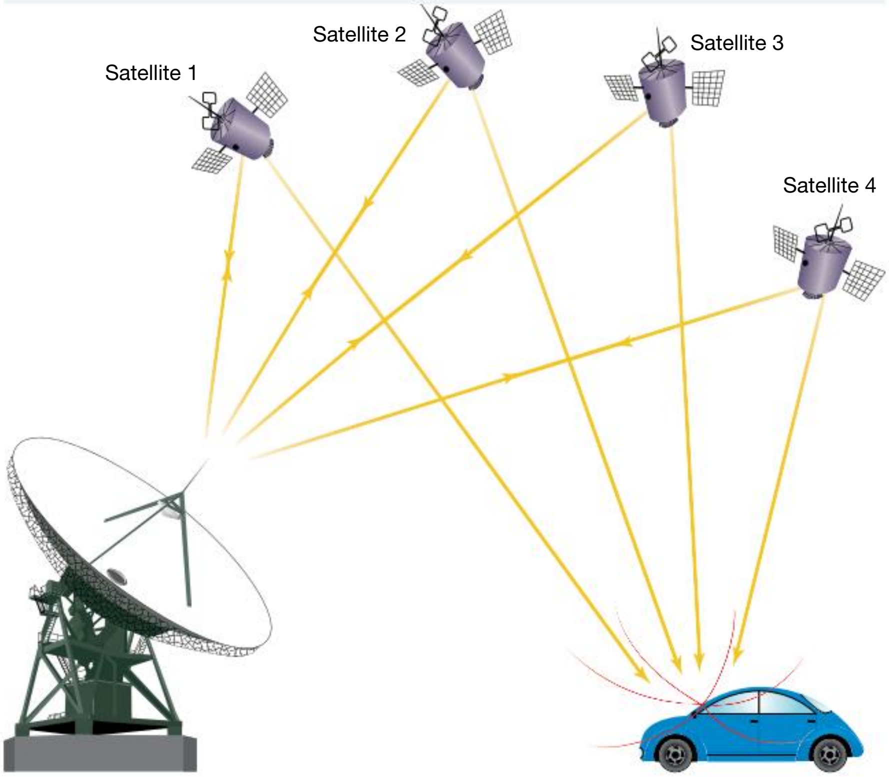
FIGURE 9.72 Geostationary satellites relay radio signals to other locations.



Navigating by satellite

The Global Positioning System (GPS) makes use of up to 32 satellites orbiting the Earth twice each day. GPS satellites orbit the Earth on different paths, all located about 20 000 kilometres above the Earth's surface. A GPS receiver uses radio signals from at least four of these satellites to accurately calculate and map your position. It can also calculate your speed, direction of movement and the distance to your destination.

FIGURE 9.73 A GPS system in a car using at least four satellites to determine your position



The GPS system was originally developed for military purposes by the US Department of Defense. The first GPS satellite was launched in 1978 and the general public became aware of its existence when it was used extensively during the Gulf War (1990–1991). It was successfully used by soldiers to locate their own position and that of other soldiers plus tanks and other vehicles. Since 1993, the GPS system has been available for use by the public free of charge and has many applications. With a GPS receiver you can now find your way around the road system, locate places of interest and even find lost dogs.

CASE STUDY: Extraterrestrial communication

You may be used to seeing science fiction shows on television where a distant spaceship communicates with Earth. Conversation happens as though the people, or aliens, are in the same room. This is, unfortunately, not possible. Space is big. Even at the maximum speed possible, the speed of light, it still takes over 8 minutes for light from the Sun to reach the Earth. If a future starship were to send a signal from our nearest neighbouring star system Alpha Centauri, it would take approximately 4.25 *years* to reach Earth. The reply would take the same time to return. This essentially means that communication over galactic distances will likely never be possible. That hasn't stopped us trying, though. Radio waves made on Earth are spreading out from us into space. They could in theory be detected in the distant future by some advanced civilisation. Similarly, we are using large radio telescopes to try to listen for a signal from the depths of space. So far, we have heard nothing …

on Resources

eWorkbook Communications (ewbk-3824)

assess on Additional automatically marked question sets

9.11 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 6, 10, 12, 14	Questions 3, 5, 7, 9, 11, 15	Questions 4, 8, 13, 16, 17

Remember and understand

1. MC How are radio waves produced artificially?
   A. Electrons in a metal rod vibrate rapidly
   B. Cold materials emit them
   C. Metals emit them
   D. Metal rods vibrate rapidly.
2. MC Sound waves cannot be directly transmitted through the air over long distances. What has to happen to them before they can be transmitted on radio waves?
   A. The sound must be added to a carrier wave
   B. The sound must be converted to an electrical signal
   C. The sound must be amplitude modulated
   D. The sound must be frequency modulated.
3. Sequence the events for the transmission of an AM signal. (You may use the phrases one or more times.)
   A. Electrical signal makes electrons vibrate in transmitter
   B. Sound energy is turned into an electrical signal with a microphone
   C. A radio wave is emitted
   D. The amplitude of the carrier wave is modified to carry the signal
   E. In FM transmissions
   F. In AM transmissions
   G. The frequency of the carrier wave is modified to carry the signal
   H. The radio wave produced before the signal is added is called the carrier wave
4. Sequence the events for the transmission of an FM signal. (You may use the phrases one or more times.)
   A. Electrical signal makes electrons vibrate in transmitter
   B. Sound energy is turned into an electrical signal with a microphone
   C. A radio wave is emitted
   D. The amplitude of the carrier wave is modified to carry the signal
   E. In FM transmissions
   F. In AM transmissions
   G. The frequency of the carrier wave is modified to carry the signal
   H. The radio wave produced before the signal is added is called the carrier wave
5. MC Which statement is true when comparing FM radio and AM radio?
   A. AM radio waves are less affected by electrical interference but AM radio waves are less able to travel around obstacles
   B. FM radio waves are less affected by electrical interference but FM radio waves are less able to travel around obstacles
   C. FM radio waves are less affected by electrical interference and AM radio waves are less able to travel around obstacles
   D. AM radio waves are less affected by electrical interference and FM radio waves are less able to travel around obstacles.

6. **MC** How are television signals carried by radio waves?
   A. The visual signal is carried on AM radio waves, and the audio signal is carried separately on FM radio waves
   B. The visual signal is carried on AM radio waves, and the audio signal is carried separately on AM radio waves
   C. The visual signal is carried on FM radio waves, and the audio signal is carried separately on FM radio waves
   D. The visual signal is carried on FM radio waves, and the audio signal is carried separately on AM radio waves.
7. Express the frequency of the following radio stations in Hz. (A frequency of 1 Hz corresponds to one complete wave being produced each second.)
   a. Triple M (FM), Melbourne: 105.1 MHz
   b. Gold AM, Bendigo: 1071 kHz
   c. Triple J (FM), Shepparton: 94.5 MHz
   d. Triple J (FM), Latrobe Valley: 96.7 MHz
   e. ABC (AM), Sale: 828 kHz
8. The wavelength (λ) of a wave is related to the frequency (f) of the wave by the equation:

$$v = f\lambda$$

   where v is the speed of the wave. The speed of radio waves in air is 300 000 000 m/s.
   Use this equation to calculate the wavelength of the carrier waves used by radio stations Triple M, Melbourne (105.1 MHz), and Gold AM, Bendigo (1071 kHz).
9. Summarise the differences between the digital and analogue signals that are added to carrier waves for television transmission.
10. How are all mobile phones different from fixed telephones in the way that they transmit and receive voice messages?
11. What are the three regions of the electromagnetic spectrum that are used to transmit data around Australia.
12. **MC** Why are repeater stations necessary for the transmission of microwaves, other radio waves and electrical signals in coaxial cables?
   A. Repeater stations receive the signals and send them on. They are only used for re-runs saving the normal stations for new programs.
   B. Repeater stations receive the signals and send them on. Without them, signals only reach one receiver.
   C. Repeater stations receive the signals and send them back to complete a circuit.
   D. Repeater stations receive the signals and send them on. Without them, signals would fade away and fail to reach their destinations.

Apply and analyse

13. Why are microwaves and other radio waves preferred for communication in the outback rather than optical fibres or coaxial cables?
14. Why are communication satellites placed in geostationary orbit?

Evaluate and create

15. The term ‘global village’ has been used to describe the Earth in recent times.
   a. Why do you think this term has been used?
   b. How has the development of long-distance communication changed the lifestyles of Australians during the past 40 years?
16. Should we be trying to communicate with alien life? How else might we look for them besides using radio waves?
17. **SIS** The table shows how many mobile phone contracts per 100 people existed in Australia between 1986 and 2006.
   a. Chart the data.
   b. Interpret the data to describe what was occurring between 1994 and 2006.
   c. Interpret the data to describe what was occurring after 2008.
   d. At some point over this period there was a slowdown in the economy. From the data can you hypothesise why this may have happened? Explain your choice.

TABLE Mobile phones per 100 people in Australia by year

Year	Number of mobile phones per 100 people
1986	0.0
1988	0.2
1990	1.0
1992	3.0
1994	7.0
1996	22.0
1998	26.0
2000	45.0
2002	65.0
2004	83.0
2006	96.0
2008	104.0
2010	102.0
2012	107.0
2014	107.0
2016	111.0

Fully worked solutions and sample responses are available in your digital formats.

9.12 The Synchrotron

LEARNING INTENTION

At the end of this subtopic you will understand why a particle accelerator is an excellent source of light and why such devices are worth the investment.

DISCUSSION

Vast amounts of money are often spent on scientific research with no obvious way of getting the money back in terms of saleable products. Discuss whether this is money well spent.

SCIENCE AS A HUMAN ENDEAVOUR: Australia's Synchrotron

Synchrotron radiation

Imagine a microscope that is tens of millions of times more powerful than the best light microscopes. It already exists. It is called a **synchrotron** and it is much, much larger than any light microscope.

There are now more than 50 of them throughout the world, including one in Australia. The Australian Synchrotron in the Melbourne suburb of Clayton is about 70 metres in diameter. The building that houses it is not much smaller than the Melbourne Cricket Ground.

synchrotron a building-sized device that uses electrons accelerated to near the speed of light to produce intense electromagnetic radiation. This is used to produce data that can describe objects as small as a single molecule.

The energy directed at the target in a synchrotron is, like visible light, electromagnetic radiation. However, it is very different from the light used in a conventional microscope.

Synchrotron radiation:
- can range from the low-energy, long wavelength infra-red part of the electromagnetic spectrum up to high-energy, short wavelength x-rays. The radiation can be 'tuned' to the energy and wavelength most suited for the purpose for which it is being used.
- is hundreds of thousands of times as intense as the radiation produced by conventional x-ray tubes. Intensity is a measure of the amount of power delivered to the target.
- is usually emitted in short pulses that last less than a billionth of a second
- is highly polarised. (The electromagnetic waves vibrate in only one direction; most light sources emit waves at random directions, which make them harder to use reliably in experiments.)

How the synchrotron works

1. Electrons are fired from a heated tungsten filament with the aid of a voltage of 90 000 volts. They reach a speed of about 159 million metres per second, 53 per cent of the speed of light.
2. The **linear accelerator** (linac) uses an even higher voltage (100 million volts) to accelerate the electrons to a speed of 99.9987 per cent of the speed of light.
3. The booster ring is used to increase the energy of the electrons before they are transferred into the storage ring.
4. In the storage ring, large magnets are used to steer the electrons. As the electrons change direction, they emit electromagnetic radiation for many hours. Magnetic fields are used to replace the energy lost by the electrons during each 'lap' of the ring.
5. The synchrotron radiation is directed into a **beamline**. The beam passes through a silicon **monochromator**, which allows only the required wavelengths to pass through.
6. The experimental station contains the target object, which is rotated so that a complete, clear image is obtained.

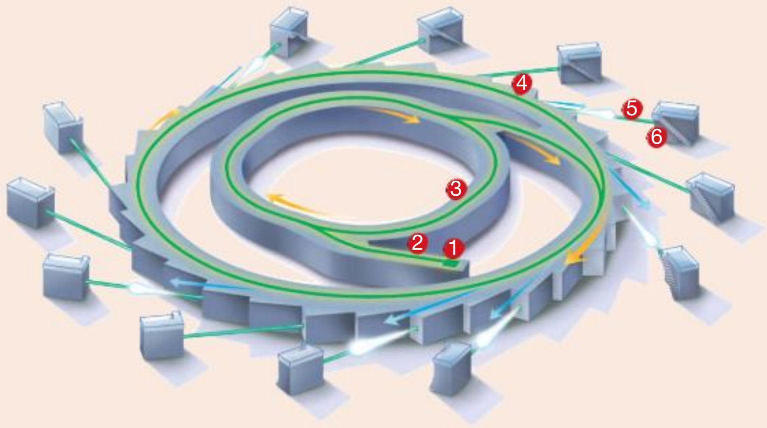
linear accelerator the part of a synchrotron that uses extremely high voltages (100 million volts) to accelerate electrons to 99.9987 per cent of the speed of light

beamline part of a synchrotron that directs radiation through a monochromator and into an experimental station

monochromator a material that allows only specific wavelengths of radiation to pass through

eles-2669

FIGURE 9.74 How the synchrotron works



Key
1 Electron gun
2 Linac
3 Booster ring
4 Storage ring
5 Beamline
6 Experimental station

The benefits of a 'super' scope

Synchrotron radiation has a wide range of applications in many areas of science and technology, including medicine, nutrition, environmental science, mining, materials, transportation, forensic science and archaeology. Some examples of the use of synchrotrons are:
- imaging proteins in the influenza virus to help develop a drug to stop it from multiplying
- the development of an artificial substance to coat the lungs of premature babies so that they can breathe more easily

- producing x-ray images of human tissue that have much more detail than conventional x-ray images. These images are being used in the fight against heart disease, breast cancer, brain tumours and many other diseases.
- the detection of weaknesses and cracks in materials used in aircraft and spacecraft
- the analysis of drill core samples in mineral exploration
- assisting in criminal investigations by more accurately identifying substances such as biological fluids, poisons, fibres and paint pigments
- identifying substances in archaeological finds such as ancient armour
- imaging molecules in chocolate to help in the production of smoother, creamier chocolate with a longer shelf life.

FIGURE 9.75 Images from a synchrotron were used to develop the drug Relenza™, which is effective in the fight against all known strains of influenza.

EXTENSION: Images from a synchrotron

Together, the characteristics of synchrotron light allow a synchrotron to produce data describing objects as small as a single molecule.

Unlike a conventional microscope, you can't actually see an image. The image has to be created from the data obtained when the radiation strikes the target with the aid of computers. However, this can happen very quickly to give, for example, a live video of air sacs in the lung inflating.

EXTENSION: How a synchrotron solved the mystery of Beethoven's death

A synchrotron was used to help solve the mystery of the death of the German composer Ludwig van Beethoven (1770–1827). During his lifetime, Beethoven suffered from loss of hearing, cramps, fevers, chronic abdominal pain, irritability and depression. Following his death, a 15-year-old fellow musician cut off a small lock of Beethoven's hair. After many years of changing hands, the lock of hair was found in a London auction house, where it was bought by the American Beethoven Society, who allowed it to be examined at a synchrotron in Chicago. It was discovered that Beethoven's hair contained about 100 times more of the heavy metal lead than today's normal level. Beethoven's symptoms were consistent with severe lead poisoning. No-one knows where the lead came from, but it could have been from the lead that was used in serving dishes, flasks and crystal glasses during Beethoven's lifetime.

on Resources

Video eLesson Australian Synchrotron (eles-1088)

assess on Additional automatically marked question sets

9.12 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2	Questions 3, 4	Question 5

Remember and understand

1. MC Which parts of the electromagnetic spectrum can synchrotron radiation consist of?
   A. All of them
   B. X-rays
   C. X-rays, UV, visible and infra-red
   D. Visible, infra-red and radio waves.
2. Fill in the blanks. Synchrotron radiation is different from light produced by a light bulb. The radiation can be __________ to the energy and wavelength most suited for the purpose for which it is being used.
   It is hundreds of thousands of times more __________ than the radiation produced by conventional sources.
   It is emitted in short __________ that last less than a __________ of a second.
3. In the Australian Synchrotron, what is the main purpose of the:
   a. tungsten filament
   b. linear accelerator (linac)
   c. booster ring
   d. silicon monochromator
   e. storage ring?

Apply and analyse

4. What makes a synchrotron such a useful tool in the fight against diseases such as influenza?

Evaluate and create

4. SIS According to the US National Institute of Standards and Technology, the speed of light in a vacuum is 299 792 458 metres per second. In a synchrotron, electrons reach a speed of 99.9987 per cent of the speed of light in the booster ring.
   a. Calculate this speed in metres per second.
   b. How much slower, in metres per second, than the speed of light are the electrons travelling?

Fully worked solutions and sample responses are available in your digital formats.

9.13 Thinking tools — Plus, minus, interesting charts

9.13.1 Tell me

What is a plus, minus, interesting chart?

A plus, minus, interesting chart (PMI chart) encourages you to look at optional viewpoints before making a decision.

They are useful to help you prepare to make a decision on something. What are the pluses, minuses and interesting points of this problem or topic?

They are also called pros, cons and interesting points.

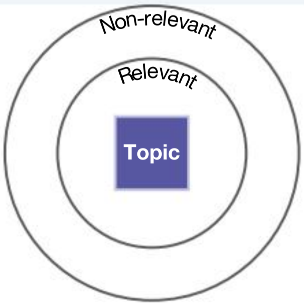
Comparing PMI charts to target maps

PMI charts and target maps both help you to think about ways to classify ideas related to the topic. Target maps sort out relevant from non-relevant material, while PMI charts show your opinions.

FIGURE 9.76 PMI chart

Topic/theme/idea		
Plus	**Minus**	**Interesting**
•	•	•
•	•	•
•	•	•
•	•	•
•	•	•
•	•	•

FIGURE 9.77 Target map



9.13.2 Show me

'Snail mail' may be slow, but it has some advantages over the faster methods of sending and receiving information such as phone, email and chatting over the internet. Creating PMI charts can help you reflect on the different ways of communicating.

1. Draw a box and write your topic or problem in it.
2. Draw three long boxes underneath your topic or problem box.
3. Fill in the three long boxes with good things and bad things about the topic, and things that you find interesting but are neither good nor bad.

FIGURE 9.79 How often do you use snail mail?

FIGURE 9.78 PMI chart example of communication by mail

Communication by post ('snail mail')		
Plus • Receive a hard copy • Receive goods, not only information • Nice to see a friend or family member's handwriting	**Minus** • Slow • Can get lost or delayed	**Interesting** • Handwriting began in 4 places independently - Mesopotamia (3400–3100 BC) - Egypt (3250 BC) - China (2000 BC) - Mesoamerica (650 BC)

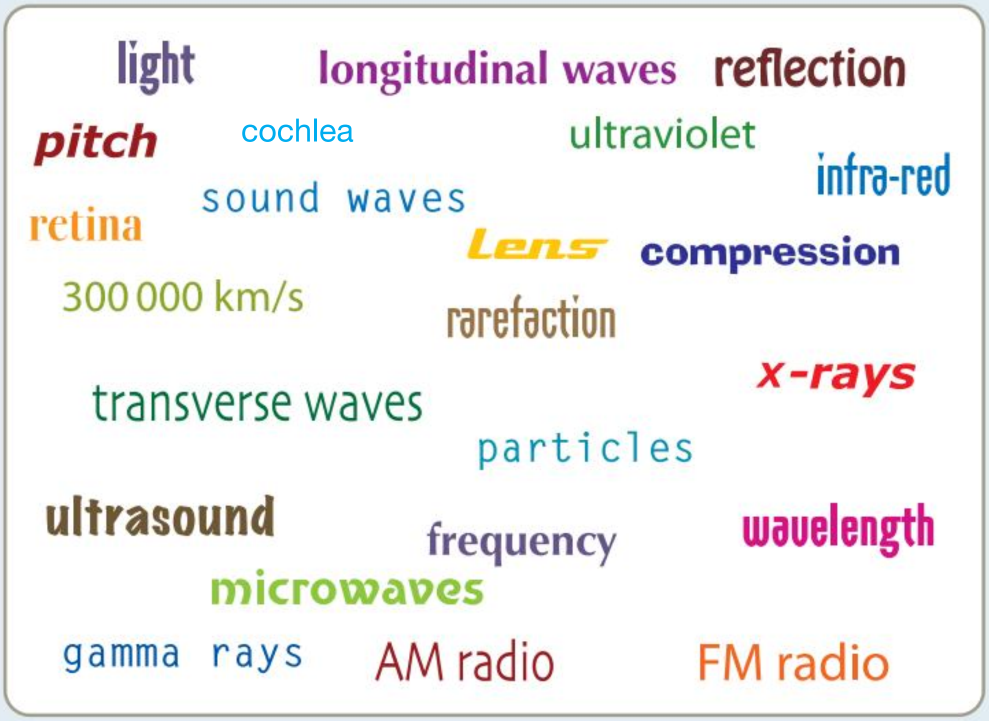
9.13.3 Let me do it

9.13 ACTIVITIES

1. With a partner or in a small group, discuss the positive, negative and interesting aspects of each of the following forms of energy transmission. Work together to create a PMI chart for each type of energy transmission to summarise your discussions.
   a. Sound
   b. Light
   c. Microwaves
   d. X-rays

2. Create a PMI chart to illustrate the positive, negative and interesting aspects of each of the following methods of communication.
   a. Mobile phones
   b. Landlines
   c. Internet

3. Create a target map on each of the following topics using the words in the box and at least three additional words that are relevant.



   a. Sound
   b. Radio waves
   c. Long-distance communication
   d. Medical diagnosis or treatment

4. Work with a partner or in a small group to create a large target map on the topic of digital communication using both words and images. Start by brainstorming a collection of words and pictures related to both digital and analogue communication.

Fully worked solutions and sample responses are available in your digital formats.

9.14 Project — Did you hear that?

Scenario

Since the invention of the Walkman — a portable cassette tape player — in 1979, through to the modern iPhone, we have loved to carry our favourite music around with us everywhere we go. Wherever you look, you'll see people walking the dog, riding the bus, going for a run, hitting the books or just sitting around hooked into an audio device of some form. With more than 220 million iPods alone sold since their release in 2001 and now the ability to listen to music on our mobile phones, more and more people are spending time plugged in. But for every person who loves having their music always available, there's another who'll be warning them that channelling all that sound directly into their ears will have long-term effects on their hearing. Your fifty-year-old principal wonders whether there aren't short-term effects as well, because she finds it difficult to hear her mobile ringing for about ten minutes after she has stopped listening to music using headphones. She comes to your science class (known for their cleverness) for some possible answers. One clever classmate suggests that maybe the type of music she was listening to had lots of high frequency sounds in it and that this had somehow affected her ear's ability to pick up the high frequencies of her mobile ring tone. Another clever classmate thinks that maybe she had the volume up too high on her headphones and that this might have caused some temporary deafness. A cheeky classmate suggests that maybe she can't hear it because she's old! Somewhat grumpy with that last comment, your principal decides that maybe she should just ban all phones in the school unless you can provide her with some thorough scientific evidence that something other than age can have short-term effects on hearing range after headphone use.

Your task

Using mobile phone music players and online hearing tests, your group will perform a series of scientific investigations to explore the short-term effects to hearing range of listening to music with headphones. You will then present your findings in the form of a scientific report suitable for sending to the principal.

Suggested factors to consider include:

- volume used
- hearing range differences between males and females
- type of music (for example, classical, jazz, R&B or pop).

Note: you will need to minimise any risk of permanently causing damage to the hearing of your human subjects by ensuring that the volume does not exceed 90 dB, and limiting trial durations to a few minutes.

on Resources

ProjectsPLUS Did you hear that? (proj-0109)

9.15 Review

Access your topic review eWorkbooks

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-3826	ewbk-3828	ewbk-3830

on Resources

9.15.1 Summary

Heat transfer

- The amount of heat energy an object has is due to the total kinetic energy of the particles of which it is made.
- At absolute zero (−273 °C) all particle movement stops.
- Temperature is a measure of the average kinetic energy of the particles, not the total energy in the object.
- Conduction occurs when a particle passes kinetic energy onto another particle.
- Materials that are poor conductors are insulators.
- Solids are usually better conductors than liquids or gases because their particles are more tightly bound and closer together.
- Convection is the movement of heat by the movement of particles. The cycle of heat movement is called a convection current.
- Sea breezes are an example of a convection current. During the day, the warm air over the land rises and the cool air over the sea rushes towards the land replacing the hot air.
- Heat can be transferred without the presence of any particles at all, as electromagnetic radiation.
- Electromagnetic radiation can be:
  - reflected
  - transmitted
  - absorbed.
- Evaporation happens when a liquid changes state to become a gas.

Controlling heat transfer

- Humans control heat flow to stay alive in various climates, for food safety and for comfort in our buildings.

Heat transfer and the planet

- The Earth's core has convection currents driven by radioactivity that drives the movement of continents through continental drift and creates a huge magnetic field, which protects the Earth from the Sun.
- The Earth's atmosphere absorbs heat and prevents it escaping into space; this is the greenhouse effect.
- Greenhouse gases create the enhanced greenhouse effect where more heat is being retained by the Earth and causing climate change.
- The changing atmospheric conditions lead to climate change due to a change in the amount of heat transfer by radiation.

Transmitting energy with waves

- Waves need vibration to travel.
- Transverse waves vibrate up and down, at right angles to the vibration.
- Longitudinal waves vibrate forward and backwards, in the same direction as the wave movement.
- Mechanical waves require particles to carry the energy.
- Electromagnetic waves do not need particles to carry the wave. They transfer their energy using fields.
- A wave can be measured by wavelength, frequency and amplitude.
- Compressions are regions of high pressure; rarefaction are regions of low pressure.

Energy transfer by sound

- Sound is a compression wave caused by vibrations.
- Sound waves require a medium to travel through and the speed changes on the medium.
- Echoes are a reflection of sound waves.
- When calculating the distance to an object, such as the depth to the sea floor, the velocity equation that follows can be used: velocity = $\frac{\text{distance}}{\text{time}}$. Remember to halve the time taken.
- Ultrasound uses echolocation to produce images for medicine.
- The distance to an object can be calculated using the concept of echolocation.

Hearing sound

- The human ear transforms sound waves into electrical signals that are sent to the brain.
- The outer ear collects sound like a funnel, and sends it through to the ear drum. The middle ear passes these vibrations, using the hammer, anvil and stirrup, to the inner ear. The hair-like cells of the cochlea attached to the receptor nerve cells send messages on their way to the brain through the auditory nerve.
- Loudness is measured in decibels (dB).
- Hearing loss can be temporary (infections, earwax build-up, a blow to the head or loud noise) or permanent (the middle or inner ear structures are incorrectly formed or damaged).
- People who have severely or profoundly impaired hearing are unable to benefit from hearing aids and may benefit from a cochlear implant, which uses a microphone to pick up sounds that are then sent as a signal to the cochlear within the inner ear.
- Most animals have two ears, which allows the brain to recognise the difference in arrival time of sound to the ears. This lets them tell where sound is coming from.

Energy transfer by light

- Any charged particle has an electric field, and if the particle moves it creates a magnetic field. Whenever a charged particle vibrates, it produces a changing electro-magnetic field.
- Electromagnetic radiation occurring across a spectrum describe the properties and uses of the waves that make up the electromagnetic spectrum: radio waves, infra-red radiation, visible light, ultraviolet radiations, x-rays and gamma rays.

Wave behaviour of light

- Models are used to understand natural phenomena.
- Wave models describe most properties of light.
- Light can also be modelled as a stream of particles, called photons, which are ‘packets of energy’.
- Luminous objects are those that emit their own visible light.
- A path of light is a ray, a stream of light rays is a beam. Beams of light are only visible when they pass through a substance that scatters the particles in the beam.
- Transparent substances allow light to pass through.
- Translucent substances scatter the light so objects cannot be seen clearly.
- Opaque substances absorb or reflect all the light striking them.
- The Law of Reflection — that the angle of incidence equals the angle of reflection.
- Refraction — when a beam enters a substance where it travels slower, it will bend towards the normal. If it enters a substance where it travels faster, it will bend away from the normal.
- The shape of a lens alters the way light passes through it. A biconvex lens converges the light to a focal point. A diverging lens (concave lens) spreads the light out; the focal point can only be traced backwards to a virtual focal point.
- Endoscopes allow light to be bent by passing it through narrow glass strands called optical fibres. They have many uses in medicine.

Seeing the light

- The screen at the back of your eye is the retina, which is lined with millions of light-sensitive cells. They send electrical signals to your brain through the optic nerve.

- The cornea is the transparent outer surface of the eye. It is curved so the light converges to the lens. The lense is a converging lens (biconvex),
- From the cornea, the light passes though a hole called the pupil. The iris (coloured part of the eye) is a ring of muscle that controls the amount of light entering the pupil.
- Images on the retina are inverted, but the brain corrects the signal so we see the correct way up.
- Short sightedness (myopia) is when the light focuses in front of the retina. Short-sighted people cannot see things in the distance clearly. It can be corrected with concave lenses.
- As people age, the lens of the eye becomes less flexible and light converges at a point behind the retina. It can be corrected with concave lenses,
- Cells in the retina respond to red, blue and green light. The mixtures of these are intercepted by our brain to make up the range of colours we see today.

Communication

- Radio waves are made up of the audio signal that is added to carrier waves.
- Receiving antennae remove the carrier wave, leaving the audio signal.
- Analogue quantities are those that can have any value and can change continually over time.
- Digital quantities are those that can have only particular values and are represented by numbers (binary code).
- Digital signals are either 'on' or 'off'. They do not experience interference like analogue signals.
- Long-distance communication of radio, television, telephone calls, facsimiles and computer data are carried over long distances using repeater stations (microwaves), coaxial cables or optical fibres (pulses of electric current).
- Mobile phones send digital signals as radio waves to a base station and switching centre and onto the correct base station to recieve the call. The base stations are a network of hexagonal cells.
- Communication via satellite occurs through signals transmitted though satellites in geostationary orbit, which orbit the Earth once every 24 hours, and so remain over the same point of the Earth at all times. Dish antennas receive the satellite signals.

The Synchrotron

- Synchrotrons are powerful microscopes that direct energy (electromagnetic radiation) at a target across a range of wavelengths.
- The radiation is hundreds of thousands of times as intense as the radiation produced by conventional x-ray tubes and in pulses less than one billionth of a second.
- Synchrotrons produce highly detailed images that have a variety of applications from medicine to identifying substances in archaeological finds.
- The Australian Synchrotron is in the Melbourne suburb of Clayton.

9.15.2 Key terms

absolute zero the lowest temperature that is theoretically possible, at which the movement of particles stops. It is zero on the Kelvin scale, equivalent to –273.15 °C.
absorbed energy hitting an object is transferred to it. This will cause the atoms in the object to vibrate more and the temperature will rise.
accommodation changing of the lens shape to focus a sharp image on the retina according to the relative location of the cell that it has been copied to
amplitude the maximum distance that a particle moves away from its undisturbed position
analogue quantities that can have any value and change continuously over time
angle of incidence the angle between an incident ray on a surface and the line perpendicular to the surface at the point of incidence, called the normal
angle of reflection the angle measured from the reflected ray to the normal
audio waves with a frequency range of sounds audible to people
auditory nerve a large nerve that sends signals to the brain from the hearing receptors in the cochlea
auricle the fleshy outside part of the ear

base station consists of antennas on top of a large tower that transmit signals from mobile phones to a switching centre
beam a wide stream of light rays, all moving in the same direction
beamline part of a synchrotron that directs radiation through a monochromator and into an experimental station
biconvex a convex lens with both sides curved outwards
binary code use of the digits 0 and 1 to represent a letter, number, or other character
binaural hearing sound detection in creatures with two ears in order to locate the source of a sound
carrier waves are radio waves that are altered in a precise way so that they contain an audio signal
cellular phones or mobile phones; so called because base stations that receive mobile phone transmissions are arranged in a network of hexagonal cells
cellular system a mobile phone system
ciliary muscles muscles that control the shape of the lens behind the iris
climate change the alteration of climate patterns on local and global scales. This is not the same as changing weather.
climate cycle any recurring pattern in global or regional climate
coaxial cables wires that can transmit a number of different signals as electrical pulses
cochlea the snail-shaped part of the inner ear in which receptors are stimulated
compression a region in which the particles are closer than when not disturbed by a wave; a squeezing force
compression wave a wave involving the vibration of particles in the same direction as energy transfer
concave curved inwards
conduction the transfer of heat through collisions between particles
convection the transfer of heat through the flow of particles
convection current the movement of particles in a liquid or gas resulting from a temperature of density difference
converging lens lens that bends rays towards each other. Converging lenses are thicker in the middle than at the edges.
convex curved outwards
core body temperature the operating temperature of an organism, especially near the centre of the body
cornea the curved, clear outer covering of your eye
critical angle when the incident angle becomes so great that the incident light can't bend any more
decibel (dB) a unit of measurement of relative sound intensity
digital quantities that can have only particular values and are represented by numbers
diverging lens lens that bend rays so that they spread out. Diverging lenses are thinner in the middle than at the edges.
ear canal the tube that leads from the outside of the ear to the eardrum
eardrum a thin piece of stretched skin inside the ear that vibrates when sound waves reach it
echo sound caused by the reflection of sound waves
echolocation the use of sound to locate objects by detecting echoes
electromagnetic waves electromagnetic energy that is transmitted as moving electric and magnetic fields. There are many different types of electromagnetic energy; for example, light, microwaves, radio waves.
endoscope a long, flexible tube with one optical fibre to carry light to an area inside the body and another optical fibre to carry light from the body to a lens. The image formed by the lens is examined or recorded.
enhanced greenhouse effect the additional heating of the atmosphere due to the presence of increased amounts of carbon dioxide, methane and other gases produced by human activity
evaporation the change of a liquid into a vapour at a temperature below the boiling point and at the surface of a liquid. Molecules with the highest kinetic energy escape, lowering the temperature of the liquid.
fields regions around an object in which each point is affected by a force of some type
focal point the focus for a beam of light rays
frequency the number of vibrations in one second, or the number of wavelengths passing in one second
gamma rays are high-energy electromagnetic radiation produced during nuclear reactions. They have no mass and travel at the speed of light.
geostationary orbit describes the path of a satellite that remains above the same location of the Earth's surface
greenhouse effect the heating of the atmosphere due to the presence of carbon dioxide, methane and other gases
heat sink device that transfers the heat generated by an electronic or a mechanical component to a coolant, often the air or a liquid, where it can be taken away from the component
hypothermia a dangerous medical condition that occurs when the body temperature is below its normal range

incident ray the ray that approaches the mirror
infra-red radiation invisible radiation emitted by all warm objects. You feel infra-red radiation as heat.
insulator material that has a very high resistance, allowing very little current to flow through it
iris the coloured part of the eye that opens and closes the pupil to control the amount of light that enters the eye
kinetic energy energy due to the motion of an object
lateral inversion reversed sideways
Law of Reflection the angle of incidence must equal the angle of reflection
lens a transparent, curved object that bends light towards or away from a point called the focus. The eye has a jelly-like lens.
linear accelerator the part of a synchrotron that uses extremely high voltages (100 million volts) to accelerate electrons to 99.9987 per cent of the speed of light
longitudinal wave *see* compression wave
luminous object that releases its own light
mantle solid but soft middle rock layer of the Earth
mechanical waves waves carried by the vibration of particles of matter
medium a material through which a wave moves
membrane a thin layer of tissue
microwave an electromagnetic wave of very high frequency
model simplified description, often a mathematical one, of a process
monochromator a material that allows only specific wavelengths of radiation to pass through
myopia *see* short sighted
normal is a line drawn perpendicular to a surface at the point where a light ray meets it
non-luminous objects that release no visible light of their own
opaque a substance that does not allow any light to pass through it
optical fibres narrow strands made of two concentric glass layers so that the light is internally reflected along the fibres
optic nerve a large nerve that sends signals to the brain from the sight receptors in the retina
ossicles a set of three tiny bones that send vibrations from the eardrum to the inner ear. They also make the vibrations larger.
oval window an egg-shaped hole covered with a thin tissue. It is the entrance from the middle ear to the outer ear.
perspiration the salty fluid produced by sweat glands under the skin
photon a particle such as a quantum of light or electromagnetism
pitch how our hearing interprets frequency. High frequency vibrations are perceived as high pitch, low frequency waves are perceived as low pitch.
plate tectonics a scientific theory that describes the relative movements and interaction of plates of the Earth's crust over the underlying mantle
pupil a hole through which light enters the eye
radiant heat heat that is transferred from one place to another by radiation
radiation a method of heat transfer that does not require particles to transfer heat from one place to another
radioactive describes atoms that are unstable and emit a particle to remove excess energy. These particles are capable of ionising other atoms upon collision, which can cause harm to living tissue.
radio waves low-energy electromagnetic waves with a much lower frequency and longer wavelength than visible light
rarefaction a region in which the particles are further apart than when not disturbed by a wave
rays narrow beams of light
receiving antenna a metal structure in which electrons are made to vibrate by radio waves or microwaves in the atmosphere
reflected ray the ray that leaves the surface of the mirror
reflection bouncing off the surface of a substance
relative sound intensity is a measure of the energy of a sound, which provides an indication of loudness. It is measured in decibels (dB) and is often referred to as sound level.
repeater station retransmits communication signals with increased energy so the signal does not fade away
retina the curved surface at the back of the eye. It is lined with sight receptors.
sampled in the context of music, means to measure the amplitude at regular intervals in order to convert a sound into a string of numbers for digital transmission

satellite an object that orbits another object. The moon is the Earth's satellite. Scientists have made and launched many artificial satellites.
scattering light sent in many directions by small particles within a substance
sea breeze the breeze that occurs when differences in air pressure cause air particles to flow from the ocean towards the land
semicircular canals three curved tubes, filled with fluid, in the inner ear that control your sense of balance
short sighted (myopia) the condition of not being able to see things clearly that are far away
SONAR the use of reflected sound waves to locate objects under water (sound navigation and ranging)
switching centres switches mobile phone calls to other base stations or to a fixed telephone system
synchrotron a building-sized device that uses electrons accelerated to near the speed of light to produce intense electromagnetic radiation. This is used to produce data that can describe objects as small as a single molecule.
threshold of hearing the lowest level of sound that can be heard by the human ear
threshold of pain the lowest level of sound that causes pain to the human ear
tinnitus a ringing or similar sensation of sound in the ears, caused by damage to the cells of the inner ear
total internal reflection the complete reflection of a light beam that may occur when the angle between a boundary and a beam of light is small
translucent allowing light to come through imperfectly, as in frosted glass.
transmitted light is passed on from one place to another through space or a non-opaque substance
transmitting antenna a metal structure in which vibrating electrons cause radio waves to travel through the air
transparent a substance that allows most light to pass through it. Objects can be seen clearly through transparent substances.
transverse wave a wave involving the vibration of particles perpendicular to the direction of energy transfer
ultrasound sound with frequencies too high for humans to hear
ultraviolet radiation invisible radiation similar to light but with a slightly higher frequency and more energy
vibrations repeated, fast back-and-forth movements
virtual focal point a common point from which rays appear to have come before passing through a concave lens
visible light a very small part of the electromagnetic spectrum to which our eyes are sensitive
wave the transmitter of energy without the movement of particles from place to place. The vibration of particles or energy fields is involved.
wavelength distance between two neighbouring crests or troughs of a wave. This is the distance between two particles vibrating in step.
wave-particle duality model that treats all objects as having both wave-like and particle-like properties. The property observed depends on the observation method chosen.
x-rays high-energy electromagnetic waves that can be transmitted through solids and provide information about their structure

on Resources

eWorkbooks	Study checklist (ewbk-3832) Literacy builder (ewbk-3833) Crossword (ewbk-3835) Word search (ewbk-3837)
Practical investigation eLogbook	Topic 9 Practical investigation eLogbook (elog-0272)
Digital document	Key terms glossary (doc-34879)

9.15 Exercise

learnON

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 4, 6, 10, 14, 15, 16, 17, 19, 22, 26	Questions 2, 5, 7, 13, 18, 20, 23, 25, 27, 30, 32	Questions 3, 8, 9, 11, 12, 21, 23, 24, 28, 29, 31, 33

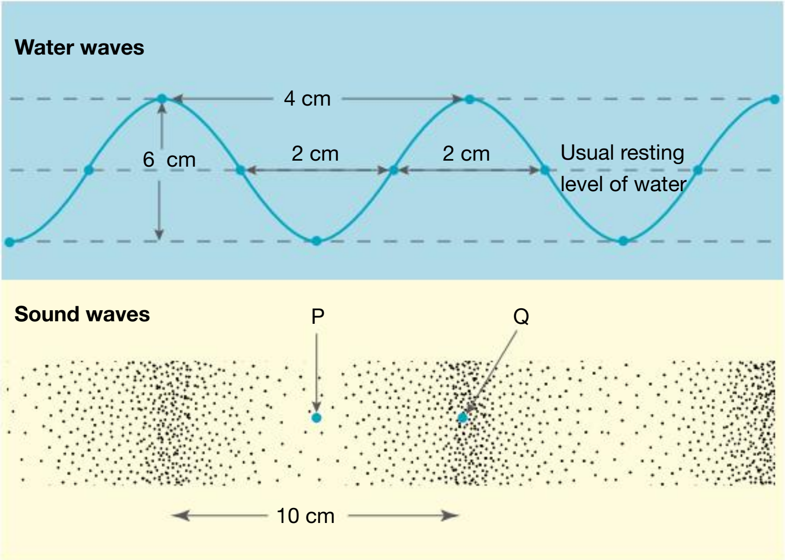
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Remember and understand

1. Briefly describe how heat is transferred from one region to another by:
   a. conduction **b.** convection **c.** radiation **d.** evaporation.
2. Identify the main method or methods by which heat is transferred to the human body by:
   a. a gas wall furnace **b.** the Sun **c.** holding a hot plate
   d. an open fireplace **e.** walking on hot coals.
3. Explain why cooks often cover meat with aluminium foil instead of plastic.
4. Explain why solids such as polystyrene, foam and wool do not conduct heat as well as most other solids.
5. Heat is always transferred from a region of high temperature to a region with a lower temperature. Explain how your body is able to keep its core temperature at 37 °C even when the air temperature is greater than 37 °C.

6. Explain how the wearing of light, loose-fitting clothes protects your body from overheating in hot weather.
7. Why do your blood vessels get larger in hot weather?
8. Explain how fibreglass batts are able to reduce the loss of heat through the ceiling by both conduction and convection.
9. Why do coastal areas experience less extreme high and low temperatures than inland regions?
10. What causes the movement of continents?
11. Explain how mountain ranges are often almost permanently surrounded by clouds.
12. What is the main atmospheric gas that is causing climate change? Why does increasing levels of this gas cause climate change?
13. Explain the difference between a transverse wave and a compression wave. List two examples of each type.

14. Refer to the water wave and sound wave shown in the figure on the right to answer the following questions.
  a. What is the amplitude of the water wave?
  b. What is the wavelength of the water wave?
  c. What is the wavelength of the sound wave?
  d. Which of the points P and Q is in the centre of a rarefaction?



15. How are ultrasound waves different from the sound waves that you can hear?
16. List some of the uses of ultrasound.
17. Replace each of the following descriptions with a single word.
  a. Regions of air in which the particles in the air are brought closer together than usual by sound waves
  b. Regions of air in which the particles in the air are moved further apart than usual by sound waves
  c. The effect of sound reflected from a hard surface over and over again
  d. What you see when you look in a mirror — even when you are not directly in front of it
18. When an object vibrates faster, what happens to the pitch of the sound it produces?
19. Explain why a hearing aid is of no use to some hearing-impaired people.
20. a. Complete the table.

Electromagnetic wave type	Wavelengths (m)	Properties
Infra-red radiation		
Gamma rays		
Ultraviolet radiation		
Light		
X-rays		
Radio		

  b. State three differences between sound waves and all of the waves listed in the table.
  c. What two properties do all of the waves listed in the table have in common?
  d. To which type of electromagnetic waves listed in the table do microwaves belong?
  e. Which of the electromagnetic waves listed in the table:
    i. can be produced artificially
    ii. transmits the most energy?
21. Which aspect of sound and light can easily be modelled with both particles and waves?

Apply and analyse

22. Which type of electromagnetic radiation is used in remote control devices?
23. What is the major use to society of:
    a. x-rays
    b. ultraviolet radiation
    c. gamma rays?
24. If there were no visible light coming from the Sun, it is obvious that we wouldn't be able to see. But the lack of visible light would cause a much greater problem. What is that problem?
25. Explain the difference in the meaning of each of the following pairs of words.
    a. Ray and beam
    b. Reflection and scattering

26. When a light ray passes from air to glass and back into air again, how does its speed change when it:
    a. enters the glass
    b. emerges back into the air?
27. Use a diagram to explain why your legs appear to be shorter when you stand in clear, shallow water.
28. Describe the role of each of the following parts of the eye.
    a. Cornea
    b. Iris
    c. Lens
    d. Retina
    e. Ciliary muscles
29. Use labelled diagrams to explain how visible light is used to transmit sound along optical fibres.
30. Describe how digital radio signals are different from analogue radio signals.
31. What does the digital transmission of television signals have in common with the analogue transmission of television signals?

Evaluate and create

32. Although electromagnetic radiation has many uses in society, there are also dangers associated with it.
    a. What danger does ultraviolet radiation pose to the human body and what measures should be taken to protect against it?
    b. Find out what precautions must be taken by the operators of x-ray equipment in hospitals.
33. a. What is synchrotron radiation and how is it 'created'?
    b. List some examples of how images obtained through the use of a synchrotron can benefit medical science.

Fully worked solutions and sample responses are available in your digital formats.

on Resources

eWorkbook Reflection (ewbk-3038)

teachon

Test maker

Create customised assessments from our extensive range of questions, including teacher-quarantined questions. Access the assignments section in learnON to begin creating and assigning assessments to students.

RESOURCE SUMMARY

on Resources

Below is a full list of **rich resources** available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

9.1 Overview

eWorkbooks
- Topic 9 eWorkbook (ewbk-ewbk-3814)
- Student learning matrix (ewbk-3155)
- Starter activity (ewbk-3816)

Practical investigation eLogbook
- Topic 9 Practical investigation eLogbook (elog-0272)

9.2 Heat transfer

eWorkbook
- Conduction and convection (ewbk-3839)

Practical investigation eLogbooks
- Investigation 9.1: Heat conduction in solids (elog-0274)
- Investigation 9.2: Radiating and absorbing radiant heat (elog-0276)

Interactivity
- Transmission, absorption and reflection (int-3400)

9.3 Controlling heat transfer

Interactivity
- Insulating your body (int-3402)

9.5 Matter and energy — Waves

eWorkbook
- Waves (ewbk-3841)

Practical investigation eLogbook
- Investigation 9.3: Moving energy without matter (elog-0278)

9.6 Energy transfer by sound

Practical investigation eLogbook
- Investigation 9.4: Sound in different media (elog-0280)

9.7 Hearing sound

eWorkbooks
- Labeling parts of the human ear (ewbk-3843)
- Sound energy (ewbk-3845)

Practical investigation eLogbooks
- Investigation 9.5: Making it seem louder (elog-0282)
- Investigation 9.6: Sound proofing (elog-0284)

Video eLesson
- Mechanism of hearing (eles-2636)

Interactivity
- Labelling parts of the human ear (int-8176)

9.9 Wave behaviour of light

eWorkbooks
- Reflection and scattering of light (ewbk-3847)
- Curved mirrors (ewbk-3849)
- Refraction (ewbk-3851)

Practical investigation eLogbooks
- Investigation 9.7: Looking at images (elog-0286)
- Investigation 9.8: How much does it bend? (elog-0288)
- Investigation 9.9: Floating coins (elog-0290)
- Investigation 9.10: Seeing the light (elog-0292)
- Investigation 9.11: Focusing on light (elog-0294)
- Investigation 9.12: Total internal reflections (elog-0296)
- Investigation 9.13: Optical fibres (elog-0298)

Video eLessons
- Twinkle twinkle (eles-0071)
- Light pipes (eles-1087)
- Galileo and the telescope (eles-1765)

Interactivities
- Bend it (int-0673)
- Lenses (int-1017)

9.10 Seeing the light

eWorkbooks
- Labelling parts of the human eye (ewbk-3818)
- The eye (ewbk-3820)

Practical investigation eLogbook
- Investigation 9.14: Getting a clearer image (elog-0300)

Video eLesson
- Human eye anatomy and common eye defects (eles-2635)

Interactivity
- Labelling parts of the human eye (int-8177)

9.11 Communication

eWorkbooks
- Investigating Morse code (ewbk-3822)
- Communications (ewbk-3824)

Video eLesson
- Communication satellite (eles-2668)

9.12 The Synchrotron

Video eLessons
- Storage ring (eles-2669)
- Australian Synchrotron (eles-1088)

9.14 Project — Did you hear that?

ProjectsPLUS
- Did you hear that? (pro-0109)

9.15 Review

eWorkbooks
- Topic review Level 1 (ewbk-3826)
- Topic review Level 2 (ewbk-3828)
- Topic review Level 3 (ewbk-3830)
- Study checklist (ewbk-3832)
- Literacy builder (ewbk-3833)
- Crossword (ewbk-3835)
- Word search (ewbk-3837)
- Reflection (ewbk-3038)

Practical investigation eLogbook
- Topic 9 Practical investigation eLogbook (elog-0272)

Digital document
- Key terms glossary (doc-34719)

To access these online resources, log on to **www.jacplus.com.au**.

10 Electricity at work

LEARNING SEQUENCE

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10.2 Static electricity 620
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10.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

10.1.1 Introduction

Electricity had fascinated, and terrified, mankind for thousands of years before we learned to harness the power of the electron. To early man, lightning was sent from the gods. It brought fire, which, though often led to destruction, could provide a burning branch to return to the family and be kept burning giving light, heat and protection. There is some evidence that early civilisations made simple batteries and they certainly produced static electricity, though they likely only saw it as an entertaining trick. As civilisation progressed, scientists noticed the link between magnetism and electricity, paving the way for motors and generators. The link between biology and electricity came when a simple experiment showed that electricity could make frog legs twitch, proving that signals to muscles are carried by electricity.

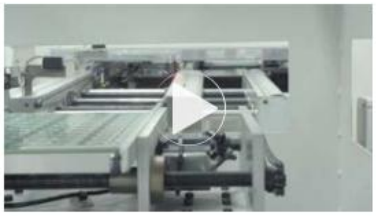
FIGURE 10.1 Deep brain electrical stimulation for treatment of Parkinson's disease

Today we use electricity for everything from a simple circuit, to the most complex electronics, from cleaning the waste gases in a power station, to stimulating brains as a treatment for neurodegenerative disorders. Figure 10.1 shows doctors implanting electrodes in a patient with Parkinson's disease. These electrodes provide deep brain stimulation (DBS) as a continuous electric current. This blocks the signals that cause the tremors of Parkinson's disease. Electricity has literally changed the world.

on Resources

Video elesson: Building electronic circuit boards (eles-4152)

Sophisticated technology allows us to create circuit boards that run a huge variety of equipment, which we use in all aspects of our lives.



10.1.2 Think about electricity

1. Why do some devices use batteries and others need to be plugged in?
2. Why do we have different types of batteries?
3. Why do we have different types of plugs (two or three pins)?
4. Why are some batteries rechargeable and others aren't?
5. When did we first start to use electricity?
6. Does electricity occur in nature or is it just a technology?
7. What would happen if we continue to burn fossil fuels?
8. Do we have an alternative to fossil fuels?
9. Will robots take our jobs?

10.1.3 Science inquiry

DATA ANALYSIS: Electricity in Mali

In Australia, most people take electricity for granted — we know when we flick a switch, the lights will come on. We have a reliable electricity source that makes our lives much more comfortable and easier than if we did not have this luxury.

Not all countries in the world have access to reliable power. In 2016, a study of 39 African countries reported that while electricity providers could supply power in the majority of these countries, individual households could not access the electricity. The study estimated that one in three Africans did not have access to a reliable source of electricity.

In this task, we will examine data for the country of Mali. Mali is the eighth-largest country in Africa and has a population of 18.54 million people, which is growing at about 3 per cent per year. In the middle ages, Mali was the centre of an empire, but it was colonised by the French in the nineteenth century. It gained independence from France in 1960, but for much of the second half of the twentieth century, it suffered devastating famines and political upheaval. The twenty-first century has seen ongoing and serious conflicts within the country and the rise of terrorism. Mali is rich in natural resources, and agriculture, livestock and gold are its main exports.

FIGURE 10.2 Mali, in the colours of its flag

TABLE 10.1 Electricity access in Mali

Year	People with access to electricity (millions)	People without access to electricity (millions)
1990	0.00	8.5
1992	0.01	8.9
1994	0.10	9.3
1996	0.60	9.3
1998	0.75	9.6
2000	1.10	9.8
2002	1.54	10.0
2004	2.00	10.4
2006	2.20	11.0
2008	3.10	11.0
2010	3.80	11.2
2012	4.10	12.0
2014	5.40	11.5
2016	6.30	11.7

Your task is to represent these data points in a suitable graph or chart. When you have finished, answer the following questions.

1. Describe what your data shows regarding the electricity infrastructure in Mali. Remember to consider both sets of data.
2. Interpret your data to find the changing percentage of the population with electricity. Use this data to evaluate whether things are getting better.
3. Mali has a rapidly growing population but is one of the poorest countries in the world. It is listed as ‘Do not travel’ by most governments due to high crime rates. Use your data to make a case for humanitarian aid for Mali. Discuss the benefits that increased access to electricity could bring.

on Resources

eWorkbooks	Topic 10 eWorkbook (ewbk-4501) Student learning matrix (ewbk-4500) Starter activity (ewbk-4503)
Practical investigation eLogbook	Topic 10 Practical investigation eLogbook (elog-0468)
learnon	Access and answer an online Pre-test and receive **immediate corrective feedback** and **fully worked solutions** for all questions.

10.2 Static electricity

LEARNING INTENTION

At the end of this subtopic you will be able to describe what charge is, how an object can become charged and how charges can produce forces.

10.2.1 Charge!

When we say that we need to charge our phones, we mean that we have to fill a battery with electrical energy. However, as we will see, electricity doesn't just sit there in a battery. You cannot hold a handful of electricity. Electricity in a circuit refers to electrons moving through the wires. We only see electricity doing something when the electrons collide with atoms in the wire and transfer their energy. This means that electrical energy is really just a type of movement (kinetic) energy. What causes the motion in the first place is the fact that electrons have a property called **electric charge**.

There are two types of charge: positive and negative. If a particle has no charge we say it is neutral.

All matter is made up of atoms. It used to be thought that they were the smallest possible pieces of matter but we now know that they are made of smaller pieces.

DISCUSSION

Why is it that sometimes your clothes crackle and you may get a small shock when you remove a jumper over your head?

Typically protons in the nucleus don't move so all of the electricity concepts that we will study are due to the movements of electrons.

All electricity is due to the movement or position of electrons.

There are two ways of using electrons. In **static electricity**, the electrons build up in one space and are not allowed to move (static means 'not moving'). If we create a pathway for electrons to flow through, we can create **current electricity** — this is how circuits work.

electric charge physical property of matter that causes it to experience a force when near other electrically charged matter. Electric charge can be positive or negative.

static electricity a build-up of charge in one place

current electricity the flow of electrons through a region

FIGURE 10.3 A neutral atom contains an equal number of protons (red) and electrons (purple). (Two of the protons are hidden in this diagram.) This diagram represents a carbon atom (6 protons and 6 electrons). The number of neutrons is not always the same as the number of protons.

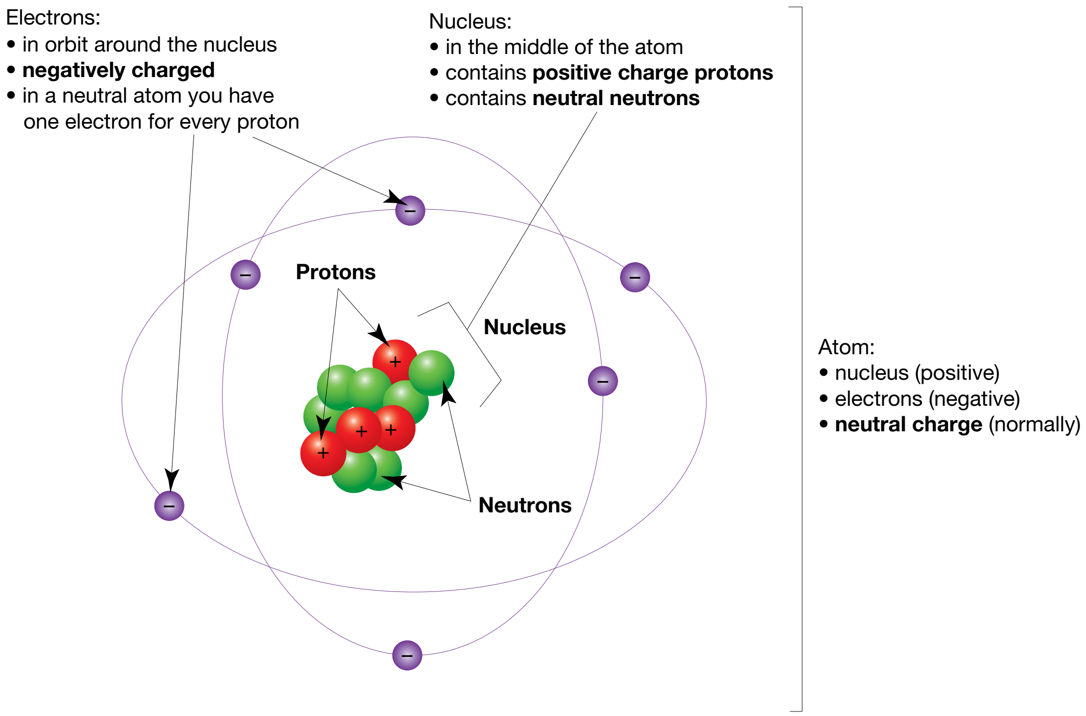


FIGURE 10.4 The cords to earbud headphones carry electricity, not sound. Each cord actually contains two wires. The jack that plugs into the player is composed of four wires, two per earbud.

10.2.2 Electric fields

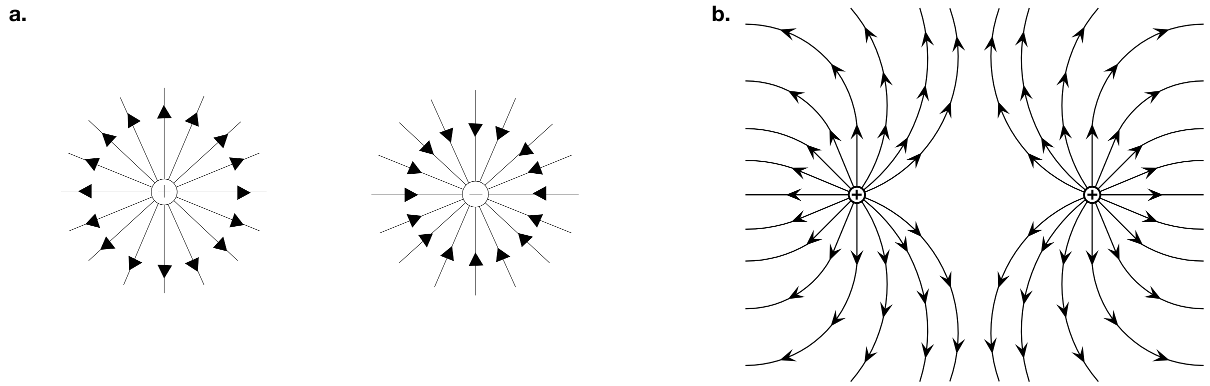
Perhaps the most important observation in all of electricity is the interaction between charges of the same and opposite signs.

Two objects with the same charge will repel, but two objects with different charges will attract.

Just as magnets are surrounded by an invisible magnetic field, all charged objects have an electric field around them. If we bring two different types of charges together the fields will join, which leads to attraction. If the charges are of the same sign, the fields cannot join and will push each other apart. This is a little bit like magnets where two north poles would repel but a north and south pole will attract. Be careful, though, not to mix up electricity and magnetism.

It is this idea that causes most of the electrical phenomena that we see.

FIGURE 10.5 a. All charged objects have an electric field around them. **b.** Two fields with the same charge will repel each other.



10.2.3 Charging by friction

Materials can be divided into:

- **electrical conductors** — these are usually metals where the presence of many free electrons allows for easy electron flow
- **electrical insulators** — can leak charge slightly, but generally do not allow it to flow. Charge can move from one insulator to another when two different insulators are rubbed together.

Some materials can steal electrons from other materials when you rub them together. The object that gains the extra electrons now has more negative charges so we say it is **negatively charged**. The object that lost the electrons now has more positive charges than negative so it is **positively charged**. This movement of electrons and attraction and repulsion between charged objects is demonstrated by the experiment in figure 10.6. The attraction between opposite charges also explains how lightning works (figure 10.7).

electrical conductors materials through which electricity flows easily

electrical insulators materials which do not allow electricity to flow easily

negatively charged having more electrons than protons (more negative charges than positive charges)

positively charged having more protons than electrons (more positive charges than negative charges)

FIGURE 10.6 When a rubber rod is rubbed with a cloth, it gains electrons. When a glass rod is rubbed with a cloth, it loses electrons. We can see the attraction and repulsion between objects when the charged rods are suspended and brought near each other.

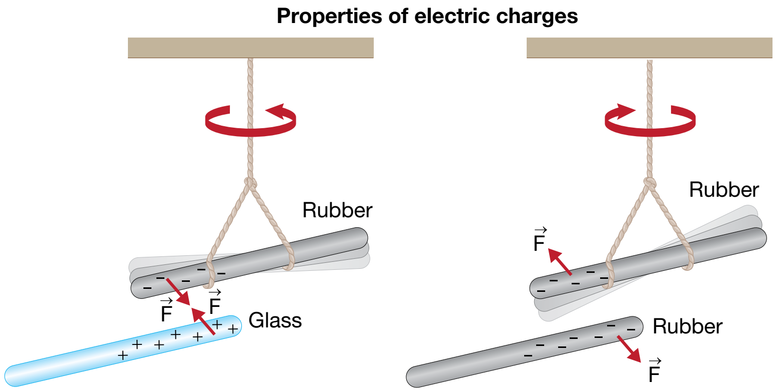
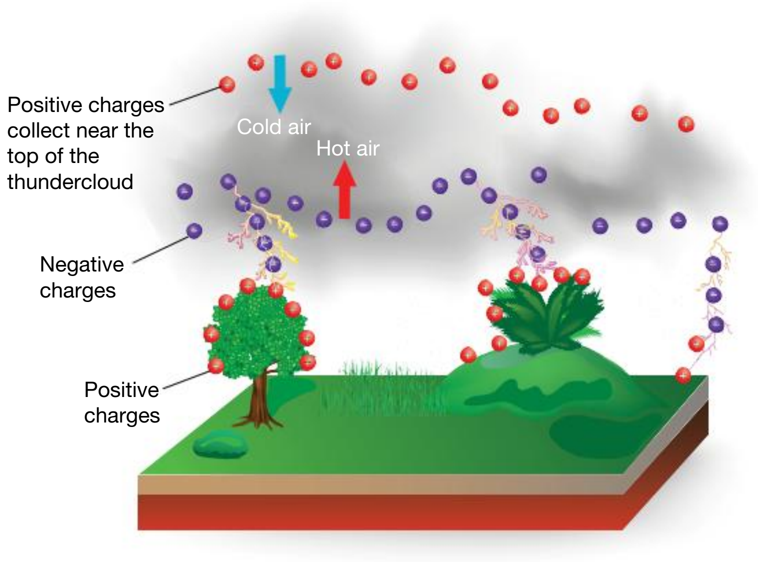


FIGURE 10.7 How lightning works. Attraction between opposite charges causes the particles to move towards one another, creating lightning.

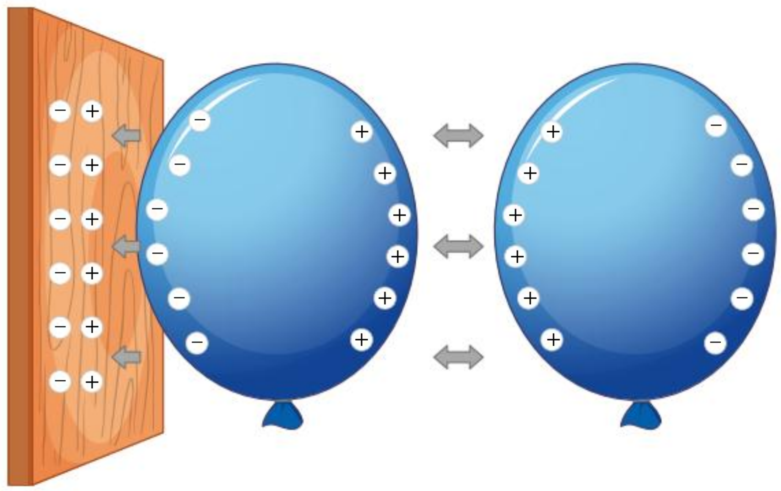


10.2.4 Charging by induction

Charged objects can attract neutral objects. If a charged object is placed near a neutral one, the electric field can repel or attract electrons in the neutral object.

- A positive charged object will attract the electrons to one side and stick to them.
- A negatively charged object will repel the electrons leaving the region close to the charged object positively charged, so again they can stick (figure 10.8).

FIGURE 10.8 A pair of balloons charged by friction will repel each other if placed with positive charge facing positive charge. If the negative side of a balloon is placed near a wall, electrons in the wall are pushed slightly away. This leaves the surface of the wall slightly positively charged, so the balloon can now stick to the wall.

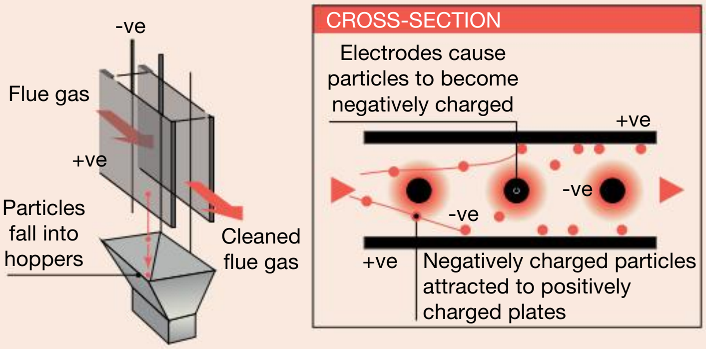


SCIENCE AS A HUMAN ENDEAVOUR: Electrostatic precipitator

Smoke rising from chimneys in power stations used to be a serious pollutant and health hazard. One of the technologies that was developed to clean up our environment is the electrostatic precipitator. Smoke particles in the waste gases pass through a series of negatively charged wires. The smoke particles pick up electrons, becoming negatively charged. They then stick to positively charged metal plates on the inside of the chimney.

The smoke no longer escapes into the atmosphere; instead it builds up into large chunks of material that can be collected and used as a building material.

FIGURE 10.9 An electrostatic precipitator is a filtration device that removes fine particles, like dust and smoke, from a flowing gas.



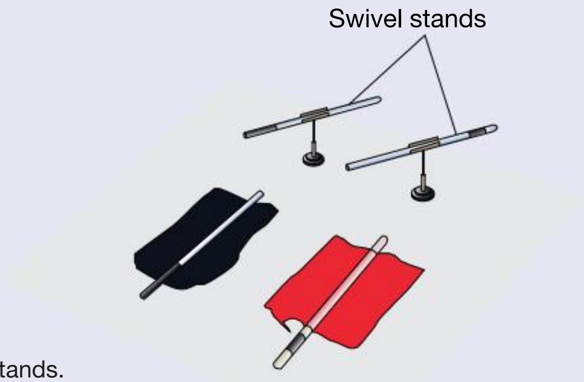
elog-0444

INVESTIGATION 10.1

Producing different charges

Aim

To investigate how different materials can be charged



Materials

- 2 glass rods
- 2 plastic rods
- wool cloth
- silk cloth
- 2 retort stands or swivel stands

Method

1. Place a glass rod and a plastic rod on separate swivel stands.
2. Put the glass rod next to the plastic rod on the swivel stand and record your observations.
3. Put the glass rod next to the other glass rod on the swivel stand and record your observations.
4. Repeat steps 2 and 3 for the plastic rod.
5. Rub the second glass rod with a silk cloth. Bring it close to the glass rod on the swivel stand and record your observations.
6. Rub the second glass rod with a silk cloth again. Bring it close to the plastic rod on the swivel stand and record your observations.
7. Repeat steps 2 and 3 for the plastic rod and a wool cloth.

Results

1. Record your observations in the table.

TABLE Observations of investigation 10.1

Material	Glass rod on swivel stand	Plastic rod on swivel stand
Glass rod		
Plastic rod		
Glass rod and silk cloth		
Plastic rod and wool cloth		

2. When the glass rod is rubbed with silk, the rod carries a positive charge. Draw a sketch of the charges on both rods when:
   a. glass rod rubbed with silk cloth is brought next to the glass rod on swivel stand
   b. glass rod rubbed with silk cloth is brought next to the plastic rod on swivel stand
   c. plastic rod rubbed with wool cloth is brought next to the glass rod on swivel stand
   d. plastic rod rubbed with wool cloth is brought next to the plastic rod on swivel stand.

Discussion

1. Explain your observations when the rods that had not been rubbed were placed next to the rods on the swivel stands.
2. When the glass rod was rubbed with silk cloth, what charges moved?
3. When the plastic rod was rubbed with wool cloth, what charges moved?
4. What are the positive charges and what are the negative charges?
5. When two rods of the same material were brought close to each other, explain what happened in terms of attraction and repulsion.
6. Give an example of electrostatic charge you see in everyday life.

Conclusion

What conclusions can you make about how charges form and move on different objects?

10.2.5 Sparks

Normally in static electricity, the electrons in a negatively charged object stay in one place — they are literally static. As the electrons all have the same negative charge the law of electrostatics says that they will be repelling each other. If there are enough electrons, the repulsion is big enough to actually push the electrons through the air to a nearby object, or often the ground. This is a spark. The object will be **discharged** or **earthed** if we allow the electrons to flow to the ground.

If the object was originally positively charged, the protons do not move; but if there is enough charge present, electrons from nearby objects or the ground can jump *into* the object. When enough electrons flow in to balance out the positive charge, again we say the object is discharged.

discharged excess charge is removed from an object, either by removing the charged particles, or adding an equal amount of charge of the opposite sign

earthed excess charge is taken away from the object, by connecting it to the ground

Sometimes when we get out of a car or remove an item of clothing quickly, we may feel a spark. These sparks happen because there is enough force to move electrons quickly across a gap. The voltage is a measure of the energy available to push the electrons. The bigger the charge the higher the voltage. Typically a spark will have thousands of volts pushing the electrons, but this should do you no harm. The current is a measure of the amount of charge flowing per second and for such sparks, this is a tiny amount. As we will see later, current is what causes damage and voltage causes electricity to push through materials.

on Resources

Video eLesson Van de Graff generator (eles-2671)

assess on Additional automatically marked question sets

10.2 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. MC How can we make a negatively charged plastic rod?
   A. Remove electrons
   B. Remove protons
   C. Add electrons
   D. Add protons
2. MC How can we make a positively charged plastic rod?
   A. Remove electrons
   B. Remove protons
   C. Add electrons
   D. Add protons
3. MC A plastic rod is rubbed with a glass rod. The glass rod becomes negatively charged. When the glass rod is held above the plastic rod, what will happen?
   A. The rods will repel
   B. The rods will attract
   C. The rods will exchange charges and neutralise
   D. Nothing
4. MC A plastic rod is rubbed with a glass rod. The glass rod becomes negatively charged. When the glass rod is held above some small pieces of paper, what will happen?
   A. The pieces of paper will repel
   B. The pieces of paper will attract
   C. The pieces of paper will exchange charges and neutralise
   D. Nothing
5. MC One end of a plastic rod is rubbed with a cloth. That end of the rod becomes negatively charged. What will be the charge at the other end of the rod?
   A. Positive
   B. Negative
   C. Neutral
   D. It depends on the type of plastic

Apply and analyse

6. MC One end of a metal rod becomes negatively charged when it touches a charged wire. What will be the charge at the other end of the rod?
   A. Positive
   B. Negative
   C. Neutral
   D. It depends on the type of metal
7. MC One end of a metal rod becomes positively charged when it touches a charged wire. What will be the charge at the other end of the rod?
   A. Positive because some of the extra protons flow to the other end
   B. Negative because the extra electrons go there
   C. Neutral
   D. Positive because electrons move from the other end to the positive end

Evaluate and create

8. Sketch and label a neutral atom with three electrons.
9. SIS Design an experiment to investigate the relationship between the amount of time a charged balloon will stick to a wall and the amount of time charging by friction occurs.
   You should:
   - develop a hypothesis
   - identify your dependent, independent and controlled variables
   - produce a suitable table
   - conduct your experiment (only take five readings)
   - plot a suitable graph of your results
   - evaluate your findings. Discuss whether your hypothesis was correct.

Fully worked solutions and sample responses are available in your digital formats.

10.3 Electrical circuits

LEARNING INTENTION

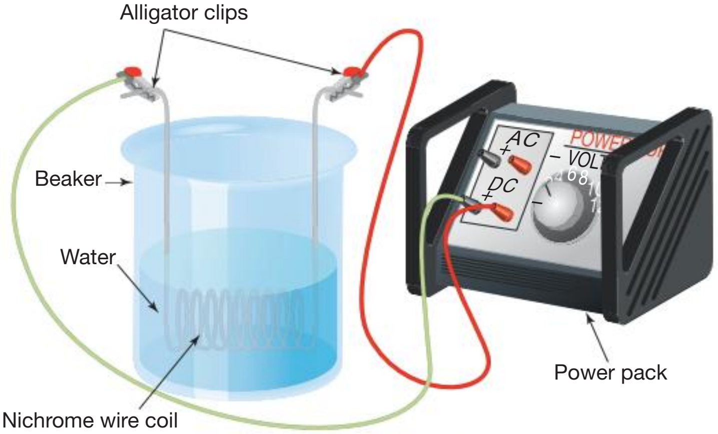
At the end of this subtopic you will be able to identify the components in a circuit, define voltage and current, and know the symbols for many components. You will be able to construct a simple circuit.

10.3.1 What is a circuit?

All electric circuits consist of three essential items:

- a **power supply** to provide the electrical energy
- a **load** (or loads) in which electrical energy is converted into other useful forms of energy
- a **conducting path** that allows electric charge to flow around the circuit.

FIGURE 10.10 This electric circuit is a model of an electric kettle. The wire coil, or the loading coil, will heat up when electrical energy is passed through it.



Power supplies

The job of a power supply is to provide a supply of electrons and push them through a wire.

Different types of power supplies include:

- batteries (one on its own is called a **cell**), used in torches and many other devices, *store chemical energy* in the substances inside them. The chemical energy is transformed into electrical energy when a chemical reaction takes place inside the cell. Many battery-operated devices use more than one battery connected in **series**. They are connected end-to-end. It is important to ensure that the positive end of one battery is connected to the negative end of the other.
- generators at power stations. The electrical energy that is used when you turn on a light switch or an appliance connected to a power point comes from a power station. This is where a generator pushes electrons.
- a solar panel, which can take the energy of sunlight and convert it directly into a flow of electrons in a circuit.

power supply a device that can provide an electric current

load device that uses electrical energy and converts it into other forms of energy

conducting path connected series of materials along which an electric current can flow

cell a single battery

series a formation of electricity-generating or using devices whereby the electricity passes from one device to the next in a single conducting loop, one after the other

DISCUSSION

Do we need wires to transfer electrical energy? If not, why do we use them?

Loads

The load in an electric circuit is an energy converter (**transducer**). It is here that most of the electrical energy carried by electric charge is transformed into useful forms of energy such as light, heat, sound and movement. In specialist light globes the load is the **filament** (figure 10.11), a coiled tungsten wire inside the globe. The filament glows brightly when it gets hot and here the load converts electrical energy into light (and thermal) energy. In a hairdryer there are two loads: a heater and a fan motor. Loads 'push back' against the power supply. We call this **resistance**. The greater the resistance, the less current can flow in the circuit.

FIGURE 10.11 The filament in this light globe is an example of a load in an electric circuit. The word filament comes from the Latin term *filamentum*, meaning 'spin'.

Conducting path

The electrical energy provided by batteries and power outlets is transformed into other forms of energy *only* when the conducting path is complete, which allows electric charge to flow through the circuit.

Conducting paths have the following features.
- In an efficient electric circuit most of the electrical energy provided by the power supply is transformed in the load.
- Some of the electrical energy is transformed in the conducting path, heating the path and its surroundings. The more this occurs, the less efficient the circuit.
- The conducting paths in the electric circuits in appliances are usually made of metals such as copper so that they have little resistance to the flow of electric charge. The conducting path in a torch consists of copper wires covered with an insulating layer of plastic.
- Any kind of break in the path such as a broken wire or burned-out component will stop the current flowing.
- A deliberate break in a circuit can be made using a **switch**. This allows you to have control over whether or not the conducting path is complete.

10.3.2 Current in circuits

The flow of electric charge is called **electric current**.
- An electric current is a measure of the amount of electric charge passing a particular point in an electric circuit every second.
- The unit of current is the ampere (A) or amp for short.

Even though the electric current in wires and most electrical devices is caused by the flow of negatively charged electrons, electric current is defined as the direction of the movement of positive charge. The electric current is said to flow through the circuit from the positive terminal of the power supply to the negative terminal.

10.3.3 Voltage in circuits

Voltage is the amount of energy that is pushing electrons around a circuit. The voltage of an entire circuit is the amount of energy provided by the power supply.

transducer a device that converts energy from one form into another form

filament coil of wire made from a metal that glows brightly when it gets hot

resistance measure of the electrical energy required for an electric current to pass through an object, measured in ohms (Ω)

switch device that opens and closes the conducting path through which a current flows

electric current a measure of the number of electrons flowing through a circuit every second

voltage the amount of energy that is pushing electrons around a circuit, per coulomb of charge that flows between two points

Electrons use all of this energy as they pass around the circuit, returning to the power supply with zero voltage. The amount of voltage used in each individual component of the circuit will add up to the total voltage of the power supply.

The voltage that is used up in each component is also known as the **potential difference** because it is the change in potential (stored) energy of the electrons as they move through the component.

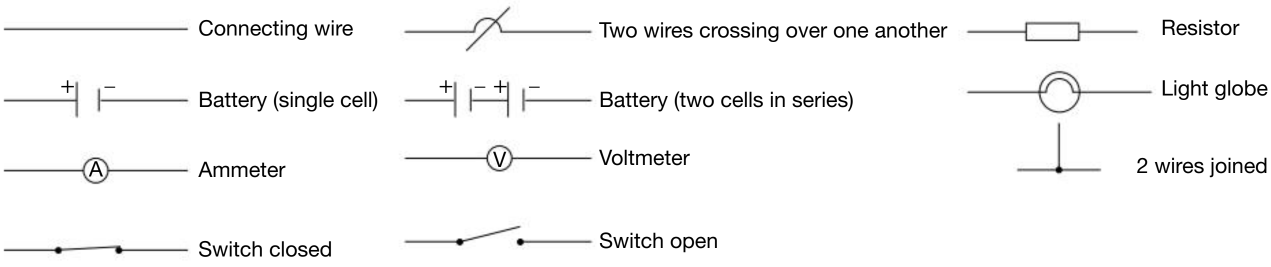
potential difference also known as voltage, is the change in the amount of energy stored in electrons as they move through a component or a circuit

circuit diagram diagram using symbols to show the parts of an electric circuit

10.3.4 Circuit diagrams: A common language

Maps of electric circuits need to be drawn so that people all over the world can read them. These maps are called **circuit diagrams**. Circuit diagrams use straight lines for connecting leads and symbols for other parts of circuits.

FIGURE 10.12 Some circuit diagram symbols



elog-0446

INVESTIGATION 10.2

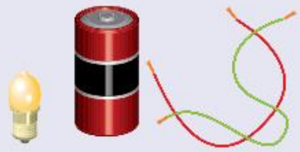
Making the right connections

Aim

To connect a battery to a light globe so that it lights up

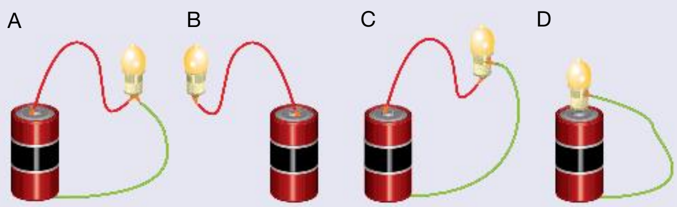
Materials

- 2.5-volt torch light globe
- 1.5-volt battery
- two connecting leads



Method

1. Connect one or two connecting leads, a 2.5-volt light globe and a 1.5-volt battery to make the globe light up.
2. Try the different arrangements as shown at A, B, C, D to see whether there is more than one way to make the globe light up.



3. Try different arrangements to see whether there are other ways to make the globe light up.

Results

1. In which of the electric circuits shown are the components correctly arranged so that the light globe will work?
2. Describe, with the aid of a diagram, any other arrangements that cause the globe to light up.

Discussion

1. Draw a flow chart to show the energy transformations that take place when the globe lights up.
2. Are all the energy transformations that take place useful? Explain your answer.

Conclusion

What conclusions can you make about creating electric circuits?

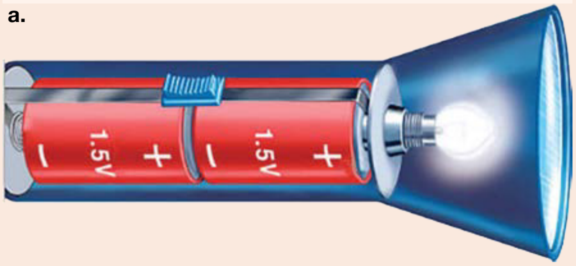
CASE STUDY: The torch circuit

Features of the torch circuit:

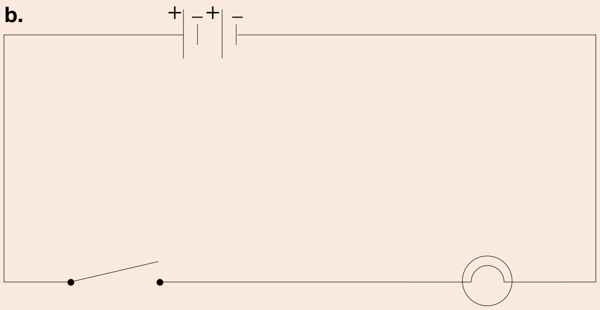
- The power supply of a torch usually consists of two or more 1.5-volt batteries connected in series. When two 1.5-volt batteries are connected in series, the total voltage is 3.0 volts. Twice as much electrical energy is available to move the electric charge around the circuit.
- The load in a torch circuit is the globe.
- When the switch is closed, electric current flows around the circuit.
- As electric charge passes through the globe, its electrical energy is released as heat in the filament. The filament is the coiled wire inside the globe. It is made of the metal tungsten and glows brightly when it gets hot.
- The conducting path consists of the spring that pushes the battery against the base of the globe (or a metal globe holder) and the metal strip that includes the switch. When the switch is open, the metal strip does not make contact with the globe and the circuit is not complete.

FIGURE 10.13 a. Components of a torch **b.** Circuit diagram for a torch

a.



b.



INVESTIGATION 10.3

elog-0448

What's inside a torch?

Aim

To investigate the electric circuit in a torch

Materials

- torch fitted with two 1.5-volt batteries
- hand lens

Method

1. Check that closing the switch makes the globe light up.
2. Unscrew the end of the torch and remove the batteries. Look closely at the batteries.
3. Look at the globe.
4. Carefully remove the globe and examine it with a hand lens.
5. Look inside the case of the torch and locate the spring and metal strip.
6. Close the switch.

Results

1. How were the batteries connected together inside the torch?
2. Draw a diagram to show what is inside the globe.

Discussion

1. What is the voltage of each battery?
2. What does the bottom of the globe touch when it is inside the torch?
3. What does the side of the globe touch when it is inside the torch?
4. Which two parts of a working torch does the spring make contact with?
5. What happens to the metal strip while the switch is being closed?
6. What does the metal strip in front of the switch touch when the switch is closed?
7. What other forms of energy is the electrical energy changed into when the circuit is closed?

Conclusion

Write a conclusion for this investigation.

ACTIVITIES

Constructing a model torch

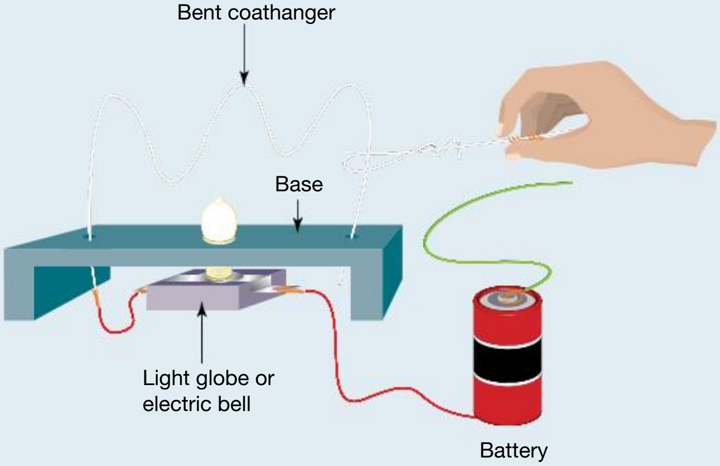
Construct your own model torch circuit using the following items: a torch globe and holder, two 1.5-volt batteries and holders, connecting leads with alligator clips or banana plugs, and a switch. Use other available materials to make your model torch circuit more realistic.

Steady-hand tester

Make a steady-hand tester. You will need: an old wire coat hanger or similar thickness wire that can hold its own shape; a loop of thin wire; wire cutters; a battery; an electric bell or light globe; connecting wires; and a shirt box, shoe box or cereal packet for the base.

The 'alarm' can be a bell hidden in the base or a globe attached to the base. Hide as much of the connecting wires as you can.

FIGURE 10.14 A steady-hand tester



Resources

eWorkbooks Conductors and insulators (ewbk-4505)
Simple circuits (ewbk-4507)

assesson Additional automatically marked question sets

10.3 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Match the components to the three essential features of all electric circuits.

Component	Essential features
a. Resistor	A. Power supply
b. Wires	B. Load
c. Battery	C. Conducting path

2. MC Which of the following correctly describes electric current and voltage?
   A. Electric current is a measure of the amount of energy passing a particular point in an electric circuit every second; voltage is a measure of the amount of electrons gained or lost by the power supply.
   B. Electric current is a measure of the amount of electric charge passing a particular point in an electric circuit every second; voltage is a measure of the amount of electrical energy in the power supply.
   C. Electric current is a measure of the amount of electric charge in the power supply; voltage is a measure of the amount of electrical energy gained or lost by electric charge as it moves through the circuit.
   D. Electric current is a measure of the amount of electric charge passing a particular point in an electric circuit every second; voltage is a measure of the amount of electrical energy gained or lost by electric charge as it moves through the circuit.
3. Some torches use three 1.5-volt batteries. What is the total voltage of such torches?

Apply and analyse

4. Match the device to its purpose.

Device	Purpose
a. Switch	A. Transducer turning electrical energy into light and heat
b. Globe	B. A means of measuring a current at a point in a circuit
c. Ammeter	C. A way of turning the current in a circuit on or off

5. Why is voltage also known as potential difference?
6. Why are connecting wires usually made of copper?

Evaluate and create

7. Describe how a torch works. Ensure that the words ‘current’, ‘energy’ and ‘circuit’ appear in your description.
8. Explain the difference between the transfer of electrical energy in a bolt of lightning and the transfer of electrical energy in an electric circuit.
9. Construct a circuit diagram of a two-battery torch with a closed switch.

Fully worked solutions and sample responses are available in your digital formats.

10.4 Battery technology

LEARNING INTENTION

At the end of this subtopic you will understand why there are many types of battery, how a battery works and how to make a simple battery.

10.4.1 Batteries

DISCUSSION

Tesla doesn't just make electric cars, they are now making huge batteries called Powerwalls for the home. Why are we starting to fit batteries to houses?

The great thing about batteries is that they are light and portable. They are used mostly in devices that need to be moved about. Imagine the disadvantages if you could only get electricity for a torch, a mobile phone or a watch by plugging it into a power point.

Batteries are also used in devices such as clock radios as a backup in case of power failure and pacemakers to keep a heart beating with the correct rhythm.

A battery is made up of two or more cells connected in series. However, in everyday language the word battery is used for a single cell. The batteries used in a torch are actually single cell. An electric cell consists of two **electrodes** and a substance through which electric charge can flow. When the two electrodes are joined together by a conducting path, a **chemical reaction** takes place inside the cell, releasing electric charge and allowing current to flow.

electrodes conductor through which an electric current enters or leaves a cell

chemical reaction a chemical change in which one or more new chemical substances are produced

The very first working battery, made by Alessandro Volta more than 200 years ago, was a tall pile of silver and zinc discs with pieces of cloth soaked in salty water between the discs. This structure became known as a voltaic pile.

on Resources

Video eLesson Volta's pile and the age of steam (eles-1777)

SCIENCE AS A HUMAN ENDEAVOUR: Why do we call it a battery?

The word battery derives from an ancient European language meaning to beat or batter something. It came to be used in legal circles, in the charge 'assault and battery', and military in the sense of a battery of guns. In the early days of cells, their electrical discharge when connected together was described as being like a battery of guns, hence a collection of cells is now a battery. The idea of things being arranged in rows then jumped to rows of caged chickens, which then became known as battery chickens. These chickens are not actually electrical!

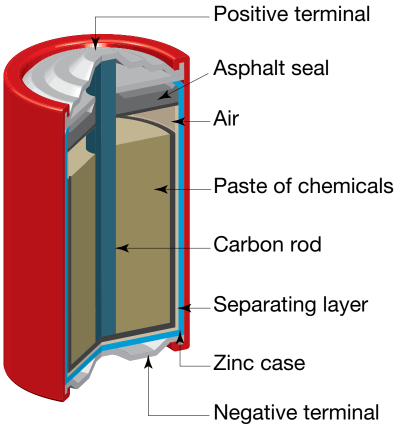
10.4.2 Dry cells

The general-purpose cells used in torches, clocks, smoke detectors and toys are filled with a paste of chemicals. The two electrodes are:

- a central rod of carbon, which is attached to the positive terminal
- a zinc case, which is in contact with the negative terminal of the cell.

When a conducting path is provided between the two terminals of the cell, a chemical reaction takes place between the paste and the zinc case. This releases electric charge, allowing an electric current to flow around the circuit. A separating layer stops the chemicals from reacting while the cell is not in use.

FIGURE 10.15 A general-purpose dry cell



These general-purpose cells are called **dry cells** because the **electrolyte** (the substance inside the cell through which electric charge moves) is not a liquid.

Other types of dry cell work in the same way but use different electrodes or electrolytes.

Alkaline cells contain an electrolyte that allows a greater electric current to flow. They are ideal for heavy-duty torches, battery-operated shavers and digital cameras.

Mercury cells produce a voltage that is much steadier than other dry cells. Their steady output makes them ideal for hearing aids, watches, calculators and measuring instruments.

FIGURE 10.16 Different types of batteries

10.4.3 Fruity cells

Citrus fruits such as lemons, oranges and grapefruit can be used to make a battery. When a conducting path is provided between different metals inserted into the fruit, a chemical reaction takes place with the acids and a small electric current flows.

dry cells devices containing chemicals as solids and pastes that react to supply an electric charge

electrolyte acid, base or salt that conducts electricity when dissolved in water or melted

on Resources

Video eLesson Fruity cells (eles-2673)

elog-0450

INVESTIGATION 10.4

A lemon battery

Aim

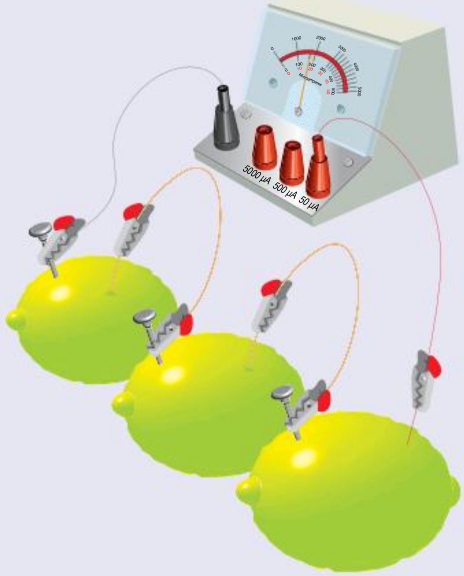
To use lemons to create a battery

Materials

- 3 lemons
- 3 galvanised nails
- three 5 cm lengths of uninsulated copper wire
- microammeter
- 4 connecting leads

Method

1. Squeeze all three lemons to break up some of the pulp inside.
2. Insert a galvanised nail and a piece of copper wire into one of the lemons. The nail and wire should be about 3 cm apart.
3. Use connecting leads to connect the negative terminal of the microammeter to the nail and the positive terminal to the copper wire.



Results

1. Record the electric current.
2. Add a second lemon in series and record the electric current again.
3. Add a third lemon in series and record the electric current.
   Investigate the effect on the electric current of:
   a. pushing the electrodes further into the lemons
   b. changing the distance between the nail and the copper wire in each lemon.

Discussion

1. What is the electrolyte in this lemon battery?
2. How did the adding of a second and third lemon in series affect the electric current?
3. How did changing the depth of the electrodes and the distance between them affect the electric current?

Conclusion

What can you conclude about using lemons to conduct electricity?

10.4.4 Car batteries

Car batteries consist of six cells connected in series. Each cell has two lead electrodes, one of which is coated with a paste of lead dioxide. The electrodes are surrounded by a sulfuric acid solution. When the battery is in use, a chemical reaction occurs between the electrodes and the sulfuric acid. One of the products of the reaction is lead sulfate. Once the engine is running, the chemical reaction is reversed and the battery recharges. The lead sulfate is converted back to lead and lead dioxide. After a few years, the lead sulfate builds up on the electrodes and becomes so hard that the reverse reaction cannot take place. The battery cannot be recharged and needs replacing.

Nickel–cadmium cells, such as those used in mobile phones, can also be recharged. A battery charger can be used to reverse the chemical reaction that causes electric current to flow.

on Resources

eWorkbook Testing batteries (ewbk-4509)

assesson Additional automatically marked question sets

10.4 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. What is the difference between a cell and a battery?
2. Complete the following sentences.
   Inside a cell an electric ___________ flows because a chemical reaction releases ___________. The ___________ of a general-purpose dry cell are made of carbon and ___________. Alkaline cells differ from general-purpose dry cells because they contain a different ___________.
3. MC Which substance makes up the electrolyte in a car battery?
   A. Hydrochloric acid
   B. Sulphuric acid
   C. Sodium hydroxide
   D. Oxygen dihydride

Apply and analyse

4. If a car battery can be recharged, why can't it last forever?
5. Why does a car battery need replacing sooner if it is not used very often?
6. Explain why mercury cells are ideal for watches, hearing aids and measuring instruments.

Evaluate and create

7. SIS Imagine a friend had been given the task of deciding which brand of AA batteries to recommend for a business to buy if they were on a tight budget. Your friend bought some batteries and used them until they ran out of power.
   The table shows the cost per pack and the time an individual battery lasted (rounded to the nearest half hour).

TABLE Comparison of battery costs and usable time

Brand	Price ($)	Number in pack	Hours lasted
CostaBattery	13	12	6.0
S-Mart	4	6	4.5
NeverReadier	1	2	3.5
Panavision	1	3	2.0
Hardacell	4	3	6.0
BunnyBatt	4	4	5.5
Idla saver pack	6	24	5.0

   a. Your friend carried out the experiment correctly. What must they have done to ensure that their readings were comparable between each of the battery brands?
   b. Plot appropriate data to test the hypothesis, more expensive brands of batteries last longer. (*Hint:* You will need to calculate some values before plotting a graph.)
   c. Evaluate the hypothesis
   d. Is there a brand that you would recommend to buy in the future? Explain why you have chosen this brand.

Fully worked solutions and sample responses are available in your digital formats.

10.5 Series and parallel circuits

LEARNING INTENTION

At the end of this subtopic you will understand the difference between series and parallel circuits. You will understand how voltage and current behave in these circuits and you will be able to build them.

10.5.1 Series and parallel circuits

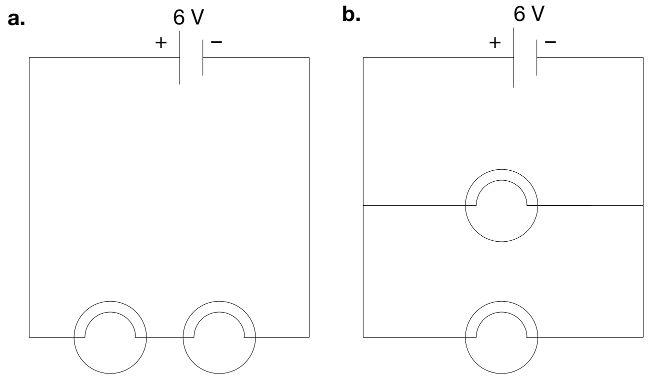
The parts of the torch circuit shown in subtopic 10.3 — the batteries, the switch and the globe — were all connected one after the other. This type of circuit is a **series circuit**. Series circuits are usually easy to connect. However, if any one part of the circuit is faulty, the connecting path is broken and nothing in the circuit will work. For example, if the Christmas tree lights in figure 10.17 were connected in series, a single faulty globe would cause all of the globes to stop glowing.

In a **parallel circuit**, each component is connected in a separate conducting path. This means if one part of the circuit is faulty, the other parts will still work. It also means that adding extra pathways allows more current from the power supply, effectively lowering the resistance. This would drain batteries more quickly, but would mean that all components can work at full power, rather than sharing voltage or using a lower current.

If the Christmas tree lights shown in figure 10.17 were connected in parallel, and one globe was faulty, the other globes will still glow. Their conducting paths would not be affected.

FIGURE 10.17 Christmas lights

FIGURE 10.18 **a.** Series circuit **b.** Parallel circuit



series circuit a circuit with the components joined one after the other in a single continuous loop

parallel circuit a circuit that has more than one path for electricity to flow through. If one of the paths has a break in it, the others will still work.

10.5.2 Voltage, current and power in series and parallel circuits

The brightness of light globes in electric circuits depends on how quickly energy flows through the globe. There are two factors that affect how quickly the energy flows:

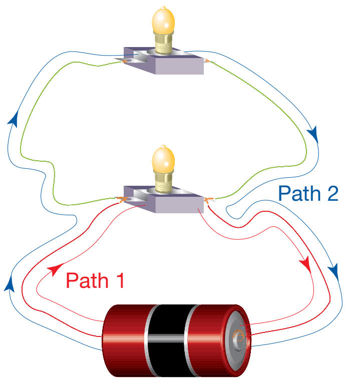
- the amount of energy transformed by each electron as it passes through the globe. The voltage across the globe is a measure of this.
- the number of electrons passing through the globe each second. The electric current passing through the globe is a measure of this.

We can change the brightness of two bulbs by arranging them in series or parallel. We must first think about what happens to voltage and current in series and parallel circuits.

Series circuits

- Current is the same at all points in the circuit.
- Adding more globes means resistance increases so less current can flow in the circuit.
- The voltage of the supply must equal the sum of the voltages across the loads. When more components are added the voltage across each component must decrease.

FIGURE 10.19 A parallel circuit has more than one conducting path.



Parallel circuits

- Adding more loops to the circuit lowers the resistance of the circuit.
- More current leaves the power supply.
- Current splits up at each branch and recombines when the wires reconnect.
- Voltage is the same across each loop of the circuit as the power supply.

This means that:

- identical globes in a series circuit have the same brightness but will be dimmer because they have to share the voltage equally and all globes have the same electric current passing through them
- identical globes in a parallel circuit have the same brightness because each branch of the circuit will have the same voltage across it. They equally share the electric current passing through the power supply.

The lights in your home are connected in parallel. Each light has the same voltage across it. Each electron gets the same amount of energy from the power supply. But different globes, bulbs and fluorescent tubes allow different amounts of electric current through. Because the brightness depends on both voltage and electric current, the brightness of the lights can differ.

FIGURE 10.20 These lights are connected in parallel. Why?

on Resources

Video eLessons The hydraulic model of current (eles-0029)
Parallel circuits (eles-2672)

Interactivity Voltage rises and fall in a simple circuit (int-5776)

DISCUSSION

If you had a bucket full of water but had a hole in the bottom, the weight of the water would provide the energy to push the water out; this is acting like the voltage. The water flowing per second is the current. What would happen to the voltage and current for this hole if a second hole (of the same size) was punched in the bottom of the bucket? How would the voltage and current compare between the holes now that there are two holes?

elog-0452

INVESTIGATION 10.5

Series and parallel circuits

Aim

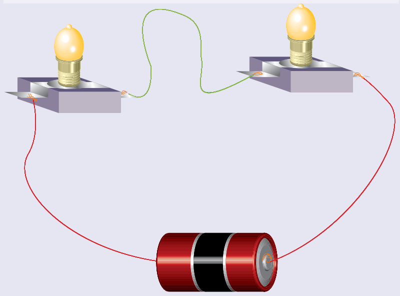
To compare series and parallel circuits

Materials

- three 2.5-volt or 3.0-volt torch globes
- 6 connecting leads

Method

Globes connected in series



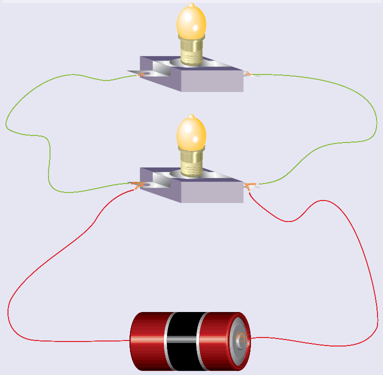
Part A: Series circuits

1. Connect one globe and the battery together with wire leads so that the globe lights up.
2. Add a second globe in series with the first globe as shown in the diagram.
3. Remove one globe from its holder.
4. Replace the globe that was removed, and then remove the other one.

Part B: Parallel circuits

5. Connect the two globes, battery and wire leads as shown in the diagram.
6. Remove one globe from its holder.
7. Replace the globe that was removed, and then remove the other one.

Globes connected in parallel



Results

Part A: Series circuits

1. Draw a circuit diagram to represent the circuit that you have connected.
2. How does the brightness of the two globes compare with the brightness of a single globe connected to the same battery?
3. What effect does the removal of one globe have on the other globe when the battery is connected?
4. Does it matter which globe is removed?

Part B: Parallel circuits

5. Draw a circuit diagram to represent the circuit that you have connected.
6. How does the brightness of the two globes compare with the brightness of a single globe connected to the same battery?
7. What effect does the removal of one globe have on the other globe?
8. Does it matter which globe is removed?
9. Outline whether the removal of one globe has any effect on the other globe?
10. What would be the effect on the other globes if a third globe was added in parallel? Design a circuit to test your prediction.

Discussion

Part A: Series circuits

1. What would be the effect on the other globes if a third globe was added in series? Test your prediction.

2. Can electric current flow in this series circuit when either globe is removed?
3. Would it be sensible to have all of the ceiling lights in your home connected in series? Give a reason for your answer.

Part B: Parallel circuits

4. Can electric current flow in this parallel circuit when either globe is removed?
5. Would it be sensible to have all the ceiling lights in your home connected in parallel? Give a reason for your answer.

Conclusion

What can you conclude about the flow of current in series and parallel circuits?

elog-0454

INVESTIGATION 10.6

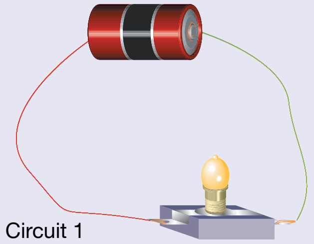
Switched-on circuits

Aim

To compare the effect of a single switch with two switches connected in parallel

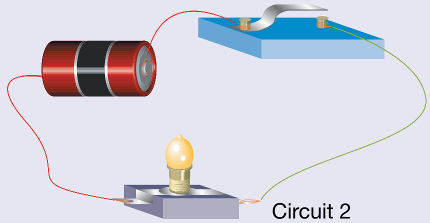
Materials

- 2.5-volt globe and holder
- 1.5-volt battery and holder
- 5 connecting leads with alligator clips or banana plugs
- 2 tapping switches



Method

1. Connect circuit 1 as shown.
2. Connect circuit 2 as shown.
3. Close the switch.
4. If nothing happens, open the switch, check that your circuit is connected properly and try again. If nothing happens this time, replace the globe.
5. Add a second switch as shown in circuit 3.



Results

Circuit 1

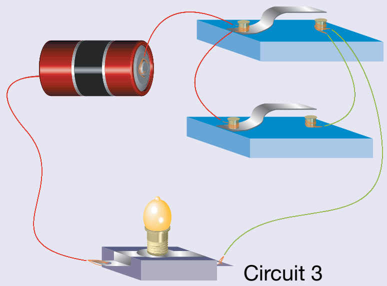
1. How can you stop the globe in circuit 1 from glowing?

Circuit 2

2. Describe what happens to the globe in circuit 2 when the switch is closed.

Circuit 3

3. Describe what happens to the light globe in circuit 3 when:
   a. neither of the switches is closed
   b. either one of the switches is closed
   c. both of the switches are closed.



Conclusion

What can you conclude about the effect of adding switches in parallel to an electrical circuit?

on Resources

eWorkbook Series and parallel circuits (ewbk-4511)

assesson Additional automatically marked question sets

10.5 Exercise

learnon

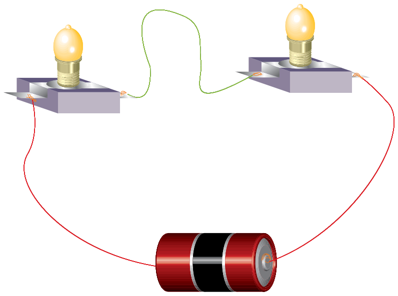
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

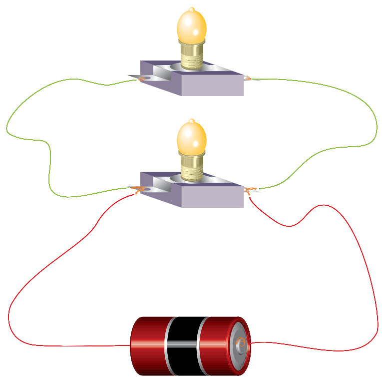
Select your pathway

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

Remember and understand

1. Complete the following sentences, by choosing the correct word from the pair of words in italics.
   a. When light globes are connected in *series/parallel*, the same electric current flows through each globe. The globes share the voltage of the power supply.
   b. When light globes are connected in *series/parallel*, the electric current splits to be shared by the globes. Each globe uses the same voltage.
2. Draw a circuit diagram of each of the circuits shown.

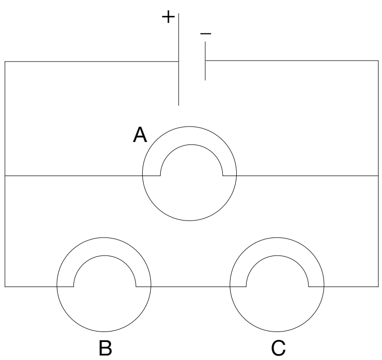




3. Explain, in words and without the use of a diagram, the difference between a circuit with two light globes in series and a circuit with two light globes in parallel.
4. Draw circuit diagrams for the following circuits. Make sure you include a switch so that you can turn the lights on and off.
   a. a cell connected to two light globes connected in series
   b. a cell connected to two light globes connected but not in series.

Apply and analyse

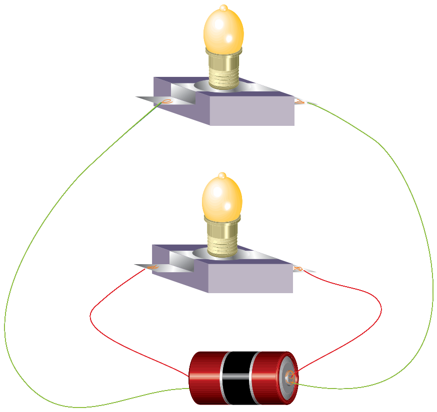
5. In a small shop, the six light globes are in series. One switch is used to switch all the lights on or off at once. Draw a circuit diagram of this circuit.
6. Examine the circuit diagram shown and answer the following questions.
   a. If the filament of globe A breaks, which globes, if any, remain working?
   b. If the filament of globe B breaks, which globes, if any, remain working?
   c. If the filament of globe C breaks, which globes, if any, remain working?



7. In a house, six light globes are in parallel. However, the lights are in separate rooms. This means that a separate switch is needed for each globe. Draw a circuit diagram of this circuit.

Evaluate and create

8. Examine the circuit shown.
   a. If the two globes are identical, how much of the current that flows through the battery flows through each globe?
   b. In what way is this circuit similar to the one in part B of Investigation 10.5?
   c. In what way is this circuit different from the one in part B of Investigation 10.5?



9. SIS Design a circuit with two switches and an electric bell, so that the bell rings only when both switches are closed. Draw a picture and circuit diagram of your circuit. Invent your own symbol for the bell. If a bell is not available, use a light globe instead.

Fully worked solutions and sample responses are available in your digital formats.

10.6 Measuring electricity

LEARNING INTENTION

At the end of this subtopic you will understand where to place ammeters and voltmeters in a circuit. You will also be able to identify any potential source for an error in a reading.

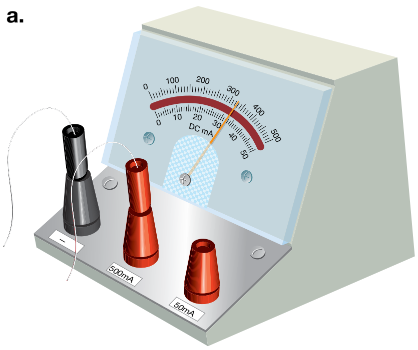
10.6.1 Ammeters

Like the currents of water in rivers and the sea, electric current can be measured.

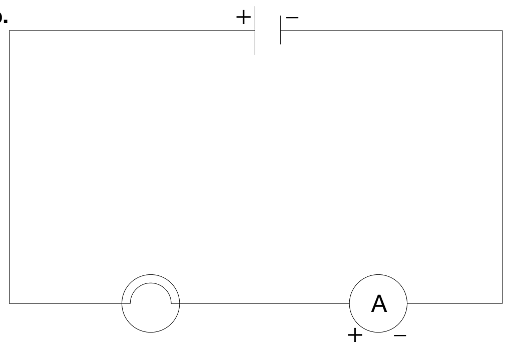
Water currents in a river or the sea can be measured by determining the amount of water that passes a particular point every second. Likewise, the size of the electric current in an electric circuit can be measured by finding the amount of electric charge passing a particular point in an electric circuit every second.

FIGURE 10.21 a. An ammeter is used to measure electric current. **b.** Circuit diagram showing how an ammeter is used to measure the electric current through a light globe

a.



b.



An **ammeter** is used to measure the size of electric current flowing in an electric circuit. An ammeter measures electric current in amperes (A) or in one-thousandths of an ampere, which are called milliamperes (mA).

ammeter device used to measure the amount of current in a circuit. Ammeters are placed in series with other components in a circuit.

Most ammeters have two positive terminals. This allows the ammeter to provide readings over a large range of currents. There is always one scale per positive terminal. Make sure you are using the scale that corresponds to the positive terminal you have plugged in.

SCIENCE INQUIRY SKILLS: Using an ammeter

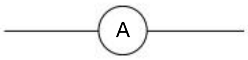
Most ammeters used in school laboratories have one (black) negative terminal and two or more (red) positive terminals. The following points are important when using ammeters. Refer to them whenever using ammeters in an investigation.

- The positive terminal of the ammeter should always be connected in series so that it is closer to the positive terminal of the power supply than the negative terminal of the power supply.
- Use the positive terminal with the highest value first. If the measured current in your circuit is smaller than the value shown on one of the other terminals, you may change the connection to the positive terminal with the smaller value.

CAUTION

Ammeters are easily damaged. If the current reading is off the scale switch the circuit off immediately.

- The scale has at least two sets of numbers on it. Use the set that matches the connected positive terminal.
- An ammeter is represented by the symbol:



- Always read an ammeter from directly in front. The error obtained by not reading from directly in front is called a **parallax error**.

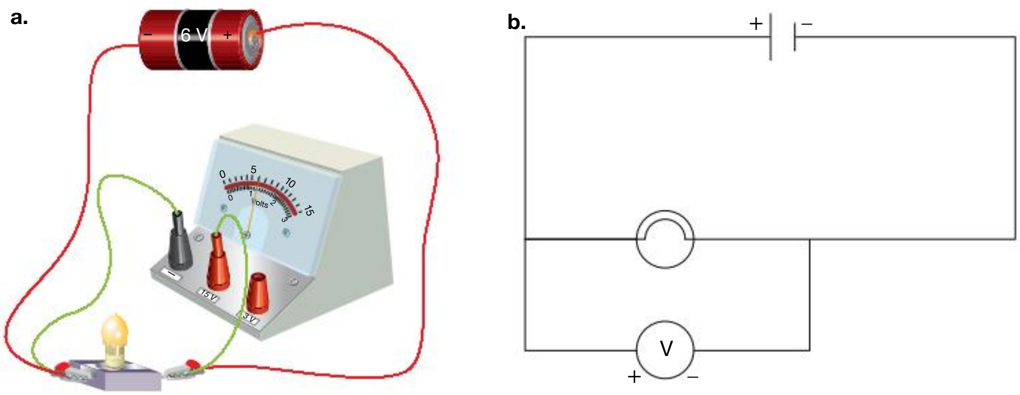
parallax error error caused by reading a scale at an angle rather than placing it directly in front of the eye

10.6.2 Voltmeters

A **voltmeter** is used to measure the voltage gain across the terminals of a power supply or voltage drop across parts of an electric circuit. Voltage is measured in volts (V).

voltmeter device used to measure the voltage across a component in a circuit. Voltmeters are placed in parallel with the components.

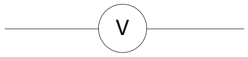
FIGURE 10.22 a. A voltmeter is used to measure the voltage gain or drop across two parts of an electric circuit. This voltmeter is being used to measure the voltage across the light globe. **b.** Circuit diagram showing how a voltmeter is used to measure the voltage drop across a light globe



SCIENCE INQUIRY SKILLS: Using a voltmeter

Like ammeters, most voltmeters used in school laboratories have one (black) negative terminal and two or more (red) positive terminals. Remember the following points when using voltmeters.

- A voltmeter should be connected in parallel with the part of the circuit across which the voltage is being measured. The positive terminal should always be connected so that it is closer to the positive terminal of the power supply than the negative terminal of the power supply.
- Use the positive terminal with the highest value first. If the measured voltage in the circuit is smaller than the value shown on one of the other terminals, you may change the connection to the positive terminal with the smaller value.
- The scale has at least two sets of numbers on it. Use the set that matches the connected positive terminal.
- A voltmeter is represented by the symbol:



- Always read a voltmeter from directly in front to avoid parallax error.

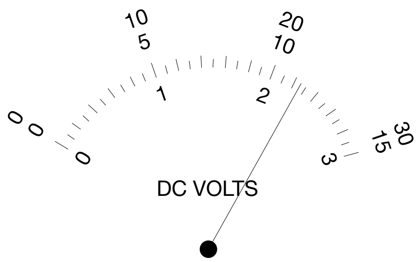
10.6.3 Errors of measurement

SCIENCE INQUIRY SKILLS: Types of error and how to avoid them

No matter how much care you take with your measurements, there will always be errors because of limitations of your equipment. In addition, when you are reading scales such as those on a ruler, a mercury or alcohol thermometer, or an ammeter or a voltmeter, you always have to make an estimate. The size of the error will depend on the size of the smallest subdivision shown on the scale. Generally, you should be able to read a scale to the nearest marking, making the error half of the smallest subdivision.

For example, on the 3-volt scale of the voltmeter shown in figure 10.23 the smallest division is 0.1 volt. With care, the scale can be read with an uncertainty of about 0.01 volt. The needle is closer to the 2.3 marking than the 2.2 marking, so the voltage can be recorded as 2.3.

FIGURE 10.23 There is always a degree of error when reading a scale like this.



Random errors

Errors that occur due to estimation when reading scales are called **random errors**. Random errors also occur when the quantity being measured changes randomly. For example, when the temperature of the water in a saucepan is being measured, it may increase or decrease slightly due to the convection currents in the water.

Systematic errors

Errors that are consistently high or low due to the incorrect use or limitations of equipment are called **systematic errors**. Parallax errors caused by consistently reading the scale of an ammeter or voltmeter from one side instead of directly in front are systematic errors. An incorrect zero reading when there is no current or voltage, or uneven scales, is also a systematic error.

Reducing errors

Random errors can be reduced by repeating measurements numerous times and calculating an average. But this is not always possible or practical. Such errors can never be totally eliminated. Some systematic errors can be eliminated by knowing how to use the equipment correctly. If a measuring instrument does not read zero when it should, the error can be eliminated by adding or subtracting the 'zero error'. But there will always be systematic errors, because no scale or measuring instrument is perfect.

random errors an error that occurs due to estimation when reading scales, or when the quantity being measured changes randomly

systematic errors errors that are consistently high or low due to the incorrect use or limitations of equipment

elog-0456

INVESTIGATION 10.7

Probing a simple circuit

Aim

To investigate the current and voltage within an open and closed circuit

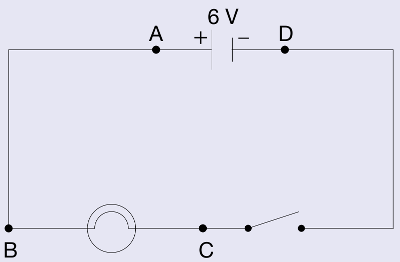
Materials

- power supply (set to 6 volts)
- 6-volt light globe and holder
- 6 connecting leads with alligator clips or banana plugs
- very long connecting lead (at least 2 m long)
- switch
- ammeter
- voltmeter

Method

Part A: Switch closed

1. Set up the circuit shown in the diagram. You should be able to set it up using only three connecting leads.
2. Use the ammeter to measure the electric current at each of the points A, B, C and D. Record your measurements in the table.



CAUTION

Check that the ammeter is connected properly before closing the switch. Ask your teacher if you are not sure.

3. Remove the ammeter from the circuit.
4. With the switch closed, use the voltmeter to measure the voltage across:
   a. the power supply (across points A and D)
   b. the light globe (across points B and C)
   c. the switch (across points C and D)
   d. one of the connecting leads (across points A and B).

Part B: Switch open

5. With the switch open, use the ammeter to measure the electric current at each of the points A, B, C and D. Before you connect the ammeter, make a prediction of the electric current at each of the four points.
6. With the switch open, use the voltmeter to measure the voltage across:
   a. the power supply (across points A and D)
   b. the light globe (across points B and C)
   c. the switch (across points C and D)
   d. one of the connecting leads (across points A and B).
   Before you connect the voltmeter, make a prediction of the voltage across each of the four items.

Results

TABLE Currents and voltages around a simple circuit

	Using the ammeter		Using the voltmeter	
	Location in circuit	**Electric current (mA)**	**Item**	**Voltage (V)**
Switch closed	A		Power supply	
	B		Light globe	
	C		Switch	
	D		Connecting lead	
Switch open	A		Power supply	
	B		Light globe	
	C		Switch	
	D		Connecting lead	

Discussion

Part A: Switch closed

1. Is there any difference between the amount of current travelling through the points A, B, C and D?
2. How does the voltage across the terminals of the power supply compare with the voltage across the light globe when the switch is closed?
3. Where is most of the electrical energy generated by the power supply lost?

Part B: Switch open

4. Were your predictions correct?
5. Why has the voltage across the switch changed so much?
6. Explain how a voltage drop can occur even though the circuit is not closed. (*Hint*: Think about what voltage measures.)

Conclusion

What can you conclude about ammeter and voltmeter readings in circuits with open and closed switches?

on Resources

eWorkbook Ammeters and voltmeters (ewbk-4513)

assess on Additional automatically marked question sets

10.6 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 5, 7, 8	Questions 3, 6, 10, 11, 13, 16	Questions 4, 9, 12, 14, 15

Remember and understand

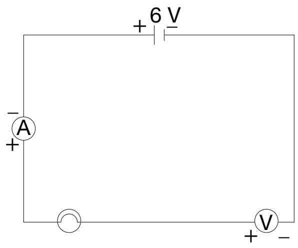
1. **MC** Which device measures the charge flowing past a point in a circuit per second?
   A. A motor
   B. A thermistor
   C. An ammeter
   D. A voltmeter
2. **MC** Which device measures potential difference?
   A. A motor
   B. A thermistor
   C. An ammeter
   D. A voltmeter
3. Describe how an ammeter must be connected in an electric circuit and state which terminal of the ammeter must be connected closest to the positive terminal of a battery.
4. Describe how a voltmeter must be connected to the part of a circuit across which the voltage is to be measured.
5. **MC** What is 0.350 A when expressed in mA?
   A. 3.5 mA
   B. 35 mA
   C. 350 mA
   D. 3500 mA
6. Explain why voltmeters and ammeters have two or three scales.

Apply and analyse

7. MC What is the correct measurement on the ammeter shown?

A. 305 mA   B. 30.5 mA
C. 3.05 mA   D. 3.05 A

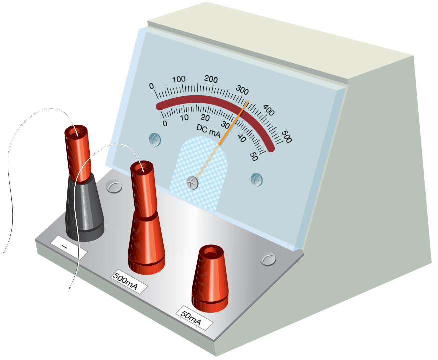
8. SIS Describe one way in which random errors can be reduced.
9. SIS Describe two causes of systematic errors when using a voltmeter or ammeter.
10. SIS Describe two causes of random errors that occur when reading scales to measure any physical quantity.
11. SIS Identify two errors in the circuit shown in the figure.



12. When using an ammeter, you are advised to use the positive terminal with the highest value scale first. If you can choose between a 50 mA and a 500 mA scale, which one should you connect first? Explain your answer.
13. SIS Is a parallax error a random or systematic error? Explain your answer.
14. SIS Can random errors be eliminated by using digital measuring instruments? Explain your answer.
15. SIS Explain why it is never possible to completely eliminate errors when measuring physical quantities.

Evaluate and create

16. SIS
a. Why can't you accurately read the electric current measure on the ammeter shown?
b. Estimate the reading.



Fully worked solutions and sample responses are available in your digital formats.

10.7 Resisting the electrons!

LEARNING INTENTION

At the end of this subtopic you will understand the meaning of electrical resistance and how to calculate it. You will be able to identify if a resistor is ohmic and be able to describe the use of components that act as sensors due to their resistance being dependent on changing environmental conditions.

10.7.1 Resistance

Imagine you are at a party with a group of friends. You all need to leave but to do so you have to push your way through a crowd of people. They are all dancing and keep getting in your way. Sometimes they bump into you. It slows you down and saps your energy. If you stop, you will be pushed by the people behind you and be made to move again. Near the exit is a corridor full of people dancing. You squeeze through but with reduced space you are pushed around more than ever! Believe it or not, this is very similar to how electrons travel through circuits.

The negatively charged electrons moving in an electric circuit have to make their way past the atoms in the connecting leads and devices that make up the circuit. The atoms are constantly vibrating and collisions between electron and atom are common. Electrical resistance is a measure of how difficult it is for electrons to flow through part of a circuit. The resistance to the flow of electric charge limits the electric current, just as the resistance of a narrow and crowded corridor limits the number of people that can pass through in a given time interval. Electrical resistance also determines how much energy is lost by electric charge as it moves through a circuit.

10.7.2 Calculating resistance

- **Conductors** have very little resistance. They allow large electric currents to flow with little loss of energy.
- **Insulators** have a very large electrical resistance. They allow very little electric current to flow.

conductors materials that have a very low resistance, allowing current to flow through them with ease

insulators materials that have a very high resistance, allowing very little current to flow through them

The letter R is used to represent resistance and its unit is the ohm (Ω).

The value of the resistance, R, of part of an electric circuit is defined by:

$$R = \frac{V}{I}$$

where V is the voltage drop in volts and I is the electric current in amperes.

A torch globe carrying an electric current of 200 mA with a voltage drop of 3 volts therefore has a resistance of:

$$\begin{aligned} R &= \frac{V}{I} \\ &= \frac{3}{0.2} \\ &= 15\,\Omega \end{aligned}$$

10.7.3 Ohm's Law

In 1827, a German physicist, Georg Simon Ohm, discovered if the voltage across a metallic conductor was doubled, the current doubled. If the voltage was tripled, the current tripled.

Ohm's Law states that the electric current in metallic conductors is proportional to the voltage drop across the conductor.

Materials that obey Ohm's Law are said to be **ohmic**. Metals and carbon are ohmic materials as long as the temperature remains fairly constant. The filament in a light globe is not ohmic.

One way of working out whether a material is ohmic is to draw a graph of voltage drop versus electric current. Recall that resistance is defined as:

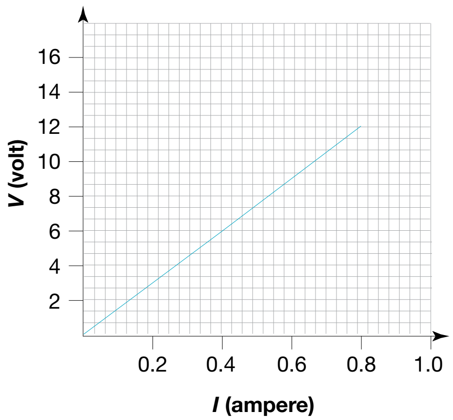
$$R = \frac{V}{I}$$

$$\therefore V = RI$$

If the material is ohmic, *R* is constant. A graph of *V* versus *I* yields a straight line (figure 10.24).

Non-ohmic materials will have curved voltage-current graphs. So if you see a curve in the graph you can immediately know that the material is non-ohmic.

FIGURE 10.24 Graph of voltage drop (*V*) versus electric current (*I*) for an ohmic conductor



10.7.4 Controlling resistance

When you turn down the volume of a radio or television, you are changing the voltage across and current flowing through parts of the electric circuits inside. The volume dial or sliding knob is part of a **variable resistor**.

Resistors are used in electric circuits to control the voltage and current. They can have a fixed resistance or can be variable like those in volume controls.

Three different types of carbon resistors are illustrated in figure 10.26. The two can-shaped resistors are a type of variable resistor used in volume dials.

FIGURE 10.25 There are several symbols that can be used to represent variable resistors.

Ohm's Law states that the current in a conductor is proportional to the voltage drop across the conductor

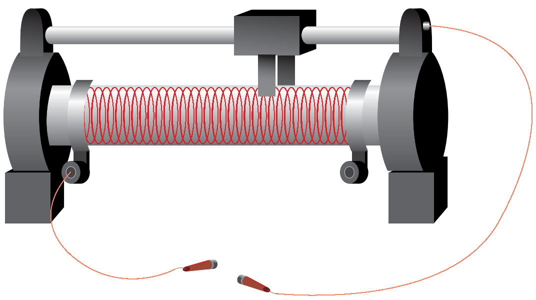
ohmic describes conductors that obey Ohm's Law

variable resistor device for which the resistance can be altered

resistors circuit component that has resistance

FIGURE 10.26 A range of carbon resistors

FIGURE 10.27 This variable resistor consists of coils of wire touched by a slider. The slider is connected to the coil and controls the number of coils through which the current flows and, therefore, the resistance.



Taking a dimmer view of things

A variable resistor can be used in a circuit like the one in Investigation 10.9 to control the voltage across the light globe and the electric current flowing through the light globe. As the resistance of the variable resistor increases, the total resistance in the entire circuit increases. This increase in resistance causes a decrease in the amount of current flowing through the circuit.

In addition, the amount of available electrical energy transformed in the globe also decreases. As the resistance of the variable resistor increases, more electrical energy is lost in heating the resistor and the surrounding air. Consequently, the globe glows less brightly because not only does less electric charge pass through it every second, but each electric charge has less energy to heat the globe's filament.

on Resources

Video eLesson Four different resistors (eles-2674)

elog-0458

INVESTIGATION 10.8

Changing resistance

Aim

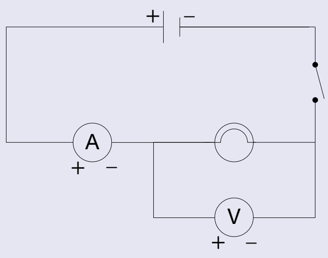
To investigate the relationship between voltage and resistance of a light globe

Materials

- power supply (variable)
- 9-volt light globe and holder
- 6 connecting leads with alligator clips or banana plugs
- switch
- ammeter
- voltmeter

Method

Part A



1. Set up the circuit shown in the diagram and leave the switch open.
2. Construct a table as shown in the Results section to record your measurements of the electric current flowing through the light globe, the voltage drop across the globe and the calculated resistance.
3. Set the power supply to 2 volts.
4. Close the switch and quickly read the meters, recording the electric current and voltage drop in your table. Ensure that the electric current is recorded in amperes (not milliamperes).
5. With the switch closed, set the power supply to 4 volts.
6. Quickly measure and record the electric current and voltage displayed on the meters.
7. Set the power supply to 6 volts (again not opening the switch) and quickly measure and record the electric current and voltage displayed on the meters.

Part B

8. Repeat the experiment; however, this time start with the power supply set to 6 volts. Then decrease it to 4 volts and then 2 volts.

Results

TABLE Part A Results

Power supply setting (volts)	Electric current (amperes)	Voltage drop (volts)	Resistance (ohms)
2			
4			
6			

TABLE Part B Results

Power supply setting (volts)	Electric current (amperes)	Voltage drop (volts)	Resistance (ohms)
6			
4			
2			

1. Calculate the resistance of the globe for each of the three power supply settings and record them in your table.
2. Plot a graph of voltage drop (V) versus electric current (I) for the light globe.
3. Plot a second graph of the voltage drop versus electric current on the same set of axes as the first graph, in a different colour.

Discussion

1. Does the resistance increase or decrease during the first part of the experiment, when the power supply setting is being increased?
2. How is the change in resistance different during the second part of the experiment, when the power supply setting is being decreased?
3. What changing property of the filament do you think caused the resistance of the light globe to change?
4. Explain any difference between the shape of the first graph and that of the second graph.

Conclusion

What can you conclude about the relationship between voltage and resistance?

elog-0460

INVESTIGATION 10.9

Making the change

Aim

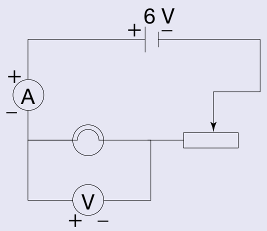
To investigate the effect of a variable resistor on a light globe connected with it in series

Materials

- power supply (set to 6 volts)
- 6-volt light globe and holder
- variable resistor
- 6 connecting leads with alligator clips or banana plugs
- ammeter and voltmeter

Method

1. Set up the circuit shown in the diagram. The variable resistor is connected in series with the light globe. Move the sliding part of the variable resistor so that the voltage drop across the light globe is at a maximum.
2. Record the voltage and current shown on the meters.



3. Move the sliding part of the variable resistor to four different positions, gradually reducing the voltage across the light globe.
4. Record the voltage and current in your table for each position.
5. Adjust the variable resistance so that the globe is at its brightest.
6. Move the voltmeter so that it measures the voltage across the variable resistor.
7. Take note of the voltage.
8. Adjust the resistance to make the globe dimmer and dimmer.
9. Take note of how the voltage across the variable resistor changes.

Results

Construct a table in which you can record five sets of measurements of voltage across the light globe and electric current flowing through the light globe.

Discussion

1. What would you expect the resistance of the variable resistor to be when the voltage drop across the light globe is at a maximum?
2. What happens to the electric current flowing through the light globe as the resistance of the variable resistor increases?
3. What happens to (a) the voltage across the light globe and (b) the brightness of the globe as the resistance of the variable resistor increases?
4. When the globe is at its brightest, what is the voltage across the variable resistor?
5. How does the voltage across the variable resistor change when the globe is made dimmer?
6. What would you expect the sum of the voltage across the light globe and the voltage across the variable resistor to be?

Conclusion

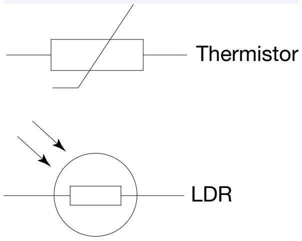
What can you conclude about varying resistance in a series circuit?

10.7.5 Sensor circuits

Light sensors

In sensors, such as those used in lights that automatically turn on when it gets dark, light dependent resistors (LDRs) are used to switch lights off and on. The resistance of LDRs changes with the amount of light falling on them, changing the voltage required to turn lights off or on. Most LDRs are made of substances that have less resistance when the light intensity increases.

FIGURE 10.28 Circuit symbols for thermistors and LDRs. These are used to change the resistance and behaviour of a circuit when environmental conditions change.



Heat sensors

Thermistors, such as those used in the heat sensors in air conditioners, refrigerators, car engine cooling systems and fire alarms have a resistance that changes as the temperature increases or decreases.

Infra-red sensors

Infra-red sensors are used in a number of devices and recent-model cars to measure distances to nearby objects. An infra-red beam is directed away from the device and the sensor detects the signal reflected from the object. A computer in the device calculates the distance and sends a warning signal or even takes action to avoid the object.

on Resources

eWorkbook Ohm's Law (ewbk-4515)

assess**on** Additional automatically marked question sets

10.7 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. MC Which of the following statements about insulators is true?
   A. Insulators have no electrons so current cannot flow.
   B. Electrons in insulators repel the electrons in the current, so it cannot flow.
   C. Insulators have an infinitely large resistance so current cannot flow.
   D. Insulators have a very large electrical resistance so only tiny currents can flow unless the voltage is high.
2. What does Ohm's Law say about the relationship between electric current in and voltage across metallic conductors?
3. What happens to the electric current flowing through a light globe when the resistance of a variable resistor in series with the globe increases?

Apply and analyse

4. Compile a list of all devices that you would expect to contain light or heat sensors. For each item, briefly state why you believe it contains light or heat sensors and how the device responds to changes in light intensity or temperature.
5. What is the voltage drop across a 100 Ω resistor when the electric current flowing through it is measured at 250 mA?
6. The electric current flowing through a light globe is measured to be 200 mA when the voltage across the globe is 1.5 volts. When the voltage is increased to 3.0 volts, the current is measured to be 360 mA.
   a. What is the resistance of the light globe when the electric current is 200 mA?
   b. Is the light globe ohmic?
   c. If the light globe were ohmic, what would happen to the electric current flowing through that light globe if the voltage across it were doubled?
7. What happens to the electric current flowing through a light globe connected in series with an LDR if the light level in the room goes down? Explain your answer.
8. What happens to the electric current flowing through a light globe connected in series with a thermistor if the temperature in the room goes up? Explain your answer.
9. Some resistors are quite small, others may have the same resistance value but be much larger and covered in ceramic. Why do you think the larger resistors are designed that way?

Evaluate and create

10. SIS Consider the following data. Sketch a graph and explain whether it represents an ohmic conductor or not. Explain your answer.

TABLE Voltage and current for a conductor

Voltage (V)	Current (A)
0	0
1	1
2	2
3	3
4	4

11. SIS Consider the following data. Sketch a graph and explain whether it represents an ohmic conductor or not. Explain your answer.

TABLE Voltage and current for a conductor

Voltage (V)	Current (A)
1	0
2	1
3	2
4	3
5	4

12. Answer these questions about the ohmic conductor.
    a. Use the graph in figure 10.24 to predict the voltage drop across the conductor when the electric current is 1.0 ampere.
    b. What electric current (in mA) flows through the conductor when the voltage drop across it is 6 volts?
    c. Calculate the resistance of the conductor.
    d. Explain how you know that the conductor is ohmic.

Fully worked solutions and sample responses are available in your digital formats.

10.8 Electronics — Smaller and smaller

LEARNING INTENTION

At the end of this subtopic you will know the most common components used in electronics. You will understand how electronics developed and predict how far they may go.

10.8.1 Electronic components

DISCUSSION

Electronics have become smaller every year. What advantages does this bring?

SCIENCE AS A HUMAN ENDEAVOUR: Tiny components

Electronics involves the use of electric circuits to control devices that make life easier, safer and a lot more enjoyable. Computers, mobile phones, televisions and remote controls are all examples of electronic devices. The parts used in the electric circuits used in electronic devices are called **components**. Larger electric appliances such as washing machines, air conditioners, clothes dryers and dishwashers — in fact any appliance that is programmable — contain electronic components.

components in circuits are the individual electrical devices that are connected in the circuit by conducting wires

The purpose of an electronic circuit is to make decisions based upon input. Obviously the circuit is not consciously making those decisions, they happen due to the design of the circuit. By having inputs such as LDRs, thermistors or just simple buttons, voltages will be controlled that turn circuits on or off. In essence the history of electronics has been the development of even smaller and faster switches.

Scaling down

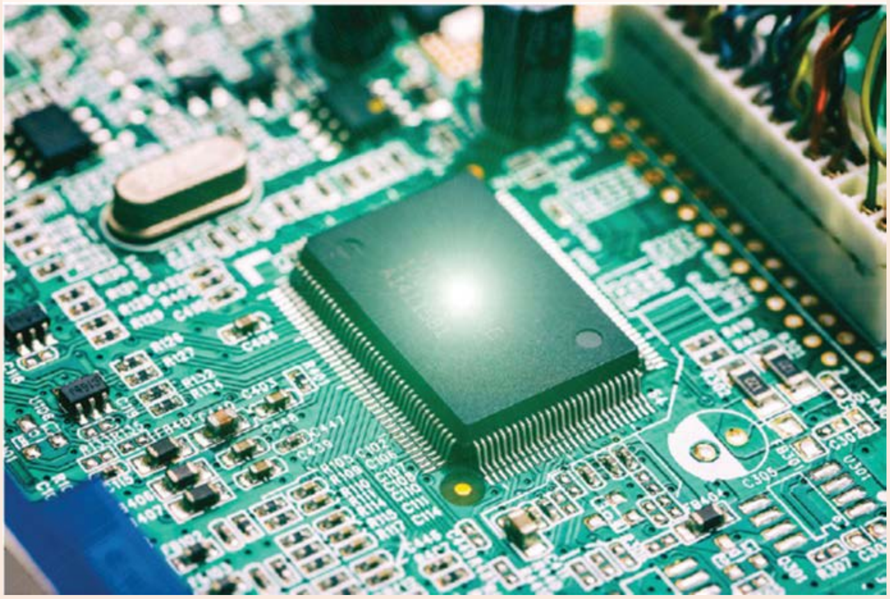
The very first electronic components, invented about 100 years ago, were very large glass tubes from which most of the air was removed. They were called vacuum tubes and for many years were used in devices such as movie projectors, radios, televisions, amplifiers and radar. The problem was that vacuum tubes were bulky, heavy and easily broken.

Most electronic components are now too small to see. **Integrated circuits** that contain thousands of tiny electronic components are etched onto thin pieces of silicon called **chips**.

The first silicon chip was developed in 1958. By 1965, most chips could hold about 30 electronic components. In 1975, a similar-sized chip could hold about 30 000 components, which allowed the development of desktop computers. Now, silicon chips no larger than the fingernail on your little finger may contain millions of electronic components. These components can be smaller than a millionth of a metre across and can be seen only with powerful microscopes.

FIGURE 10.29 A vacuum tube

FIGURE 10.30 The silicon chips on the memory cards in computers contain millions of different electronic components.



The first computers

The first fully electronic general purpose computer, built in 1946, weighed 27 tonnes and occupied three floors of an office building because of the weight and size of its components. The same functions can now be performed faster by your mobile phone.

integrated circuits electric circuits made up of miniature components that can be etched onto silicon chips

chips tiny pieces of silicon onto which tiny electric circuits can be etched

10.8.2 Electronic building blocks

Apart from resistors, some of the most common electronic components are capacitors, diodes and transistors.

Capacitors — Storing charge for a while

Capacitors store electric charge for a short time before allowing it to flow to other parts of a circuit. The amount of charge that can be stored for each volt across a capacitor is called its capacitance. Capacitance is measured in units of farad (F) or microfarad (μF). A microfarad is one-millionth of a farad. Capacitors have some advantages over cells.

- They can release their charge in a highly controllable way, often much more quickly than a cell could.
- They can be made to be very lightweight.
- They are used to allow for a sudden burst of current, such as in electronic camera flashes.

FIGURE 10.31 A capacitor and its symbol

Drones are often powered by lightweight capacitors because heavy batteries would reduce their flight time and manoeuvrability. Capacitors can be dangerous if you accidentally discharge one through you, because the current can be high enough to burn or even kill.

Diodes — One-way streets

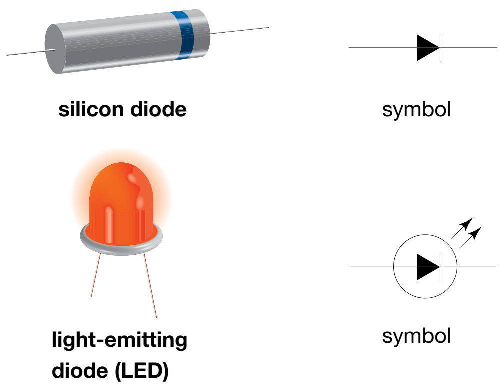


FIGURE 10.32 Diodes and their symbols

Diodes allow electric current to travel through them in only one direction. This might sound like a disadvantage, but it is actually quite useful to have a component that acts as a valve for electricity. They look like small resistors but have a single band at one end. This end of the diode is the negative end and should be connected closer to the negative terminal of the power supply than the positive terminal.

Light-emitting diodes (LEDs) also allow current to flow in only one direction but *transform electrical energy into light energy*. LEDs are often used as indicator lights in electrical appliances. An arrangement of seven LEDs can be used in devices such as watches, clocks and digital meters to display any number between 0 and 9. The display circuit is designed so that the LEDs light up in different combinations. LEDs are now used extensively in household and commercial building lighting because they use less energy than older lighting devices. For this reason, LEDs have replaced traditional tungsten filament (incandescent) light bulbs, but it is now possible to buy LED filament globes that resemble traditional globes in look and light distribution, and produce light through a series connected string of diodes.

FIGURE 10.33 LED filament bulbs resemble traditional light bulbs but use much less electricity.

light-emitting diodes a device that emits visible light when a current, which flows in one direction only, passes through it

EXTENSION: Liquid crystal displays

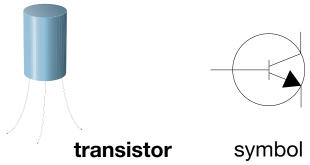
Liquid crystals are often used instead of LEDs for the same purpose. Small voltages cause the molecules in liquid crystals to rearrange themselves, changing the colour of the crystals. In an LED TV, LEDs are used to light an LCD display. As the LEDs are always on and the LCDs are not completely opaque, some light always gets through meaning that black regions of the picture don't look completely black. Organic LED (OLED) screens are a newer technology. The pixels of an OLED screen are self-illuminating meaning they produce both colour and light from a single diode. This removes the need for a separate backlight and so they can turn off completely giving true black shades. They also have a wider viewing angle than regular LED screens.

FIGURE 10.34 OLED television

Transistors — Switches on three legs

Transistors are the smallest electronic switches that we have. Their invention in 1947 revolutionised our technology. They work by changing the size or direction of electric current as a result of very small changes in the voltage across them. This makes them ideal for use in devices that amplify sound. However, they have many other uses and most electronic devices contain chips that hold many microscopic transistors.

FIGURE 10.35 Transistors and their symbols



10.8.3 Chips with everything

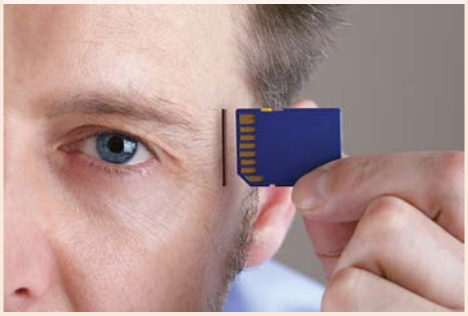
A silicon chip that is able to store information, process it and control other electric circuits is called a **microprocessor**. Since their development in 1971, microprocessors have been used in calculators and computers. As they became less expensive they began to be used in household appliances such as microwave ovens, televisions and washing machines. The microprocessors made them 'programmable' and able to perform tasks with little human effort. They are now used in robots, cars, phones and many other devices that store and process information.

microprocessor electronic central processing units of computers on a microchip

SCIENCE AS A HUMAN ENDEAVOUR: Cyborgs

The word cyborg is short for cybernetic organism, a term first used in 1960, predicting the extension of human abilities by implantation of electronic components. Over the last few years there have been a number of devices that have started to connect humans directly with technology. We have already seen cochlear implants allowing people with hearing loss the ability to hear again. Retinal implants are still in their infancy and, while offering very poor 'picture quality', have proven that electronic reproduction of vision is possible. People have even had chips connected to their nerves so that they can control devices by thought. How long is it before the technology becomes so powerful that people decide to become electronically enhanced?

FIGURE 10.36 How long will it be before we can download files directly to our brains?



on Resources

Interactivity Electronic building blocks (int-5781)

assess on Additional automatically marked question sets

10.8 Exercise

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Question 1	Questions 2, 4	Question 3

Remember and understand

1. MC What is on the pieces of silicon that make silicon chips so useful?
   A. Just one electronic component per chip
   B. Circuits containing electronic components
   C. Millions of vacuum tubes
   D. One capacitor per chip

Apply and analyse

2. How is a microprocessor different from other silicon chips?
3. Describe three advantages that today's electronic components have over the vacuum tubes that were first used in devices such as televisions and movie projectors.

Evaluate and create

4. Complete the table below.

Component	Circuit symbol	Function
Capacitor		
Diode		
LED		
Transistor		

Fully worked solutions and sample responses are available in your digital formats.

10.9 Electricity and magnetism

LEARNING INTENTION

At the end of this subtopic you will understand what a magnetic field is and how it is produced by permanent magnets and electromagnets.

DISCUSSION

Magnets may be entertaining, but are they really useful? What do we use magnets for?

10.9.1 Faraday and magnetism

When you are at home, most of the electricity you use is obtained by simply plugging a lead into a power point and flicking a switch or two. The electric current that flows from power points in most homes is generated by power plants that are many kilometres away. The generation of electricity by power plants, whether they are coal-fired, gas-fuelled or hydroelectric, depends on the close relationship between electricity and magnetism.

SCIENCE AS A HUMAN ENDEAVOUR: Michael Faraday

The first person to link electricity and magnetism in a practical way was Michael Faraday. Faraday was born on 22 September 1791 to a poor family in London, England. He received little schooling and was essentially self-educated. Several years after Danish scientist Hans Ørsted discovered that electric currents produced magnetic fields, Faraday suggested that perhaps a magnetic field might produce an electric current. In 1831, Faraday succeeded in generating an electric current by moving a coil of wire through a magnetic field. He had made the very first **electric generator**, also known as a **dynamo**. He went on to discover how electricity can interact with magnetism to produce motion. This led to him developing the world's first electric motor.

Faraday gave his discoveries to the world and took no profit from them. He simply wanted to make the world a better place.

FIGURE 10.37 Michael Faraday discovered how to harness electricity by inventing the motor and generator.

Magnets attract iron and alloys containing iron. They also attract alloys containing nickel and cobalt, which, like iron, have magnetic properties.

Features of magnets:

- All magnets, no matter their shape, have a **north pole** and a **south pole**.
- Like poles of magnets repel while unlike poles attract.
- **Permanent magnets** retain their magnetism at all times.
- **Temporary magnets** (like the nail suspended from the permanent magnet in figure 10.38) lose their magnetism when removed from other magnets.

A **magnetic field** is the region in which a magnetic force exists. A 'map' of a magnetic field around a bar magnet is shown in figure 10.39. It shows the direction of the magnetic force on the north pole of another magnet placed in the field. The direction of the magnetic force is defined as flowing away from the north pole and towards the south pole. A compass needle is a small magnet that lines itself up with the magnetic field. It always points in the direction of the magnetic force as the north of the compass experiences a force in the direction of the arrows.

electric generator device that transforms kinetic energy of rotation into electrical energy

dynamo electric generator

north pole end of the magnet that when free to rotate, points to the north pole of the Earth

south pole end of a magnet opposite the north pole

permanent magnets magnets that retain their magnetic effect for many years

temporary magnets magnets that stay magnetic while in contact with a permanent magnet, or one that is magnetic for a very short time

magnetic field area where a magnetic force is experienced by another magnet. The direction of the magnetic force is shown by drawing field lines; the size of the force is shown by how close together the lines are.

FIGURE 10.38 The nail is a temporary magnet while it is in contact with the permanent magnet.

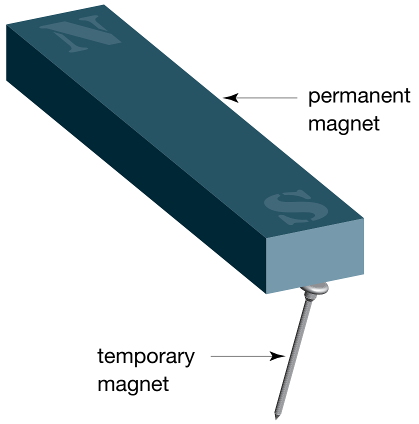
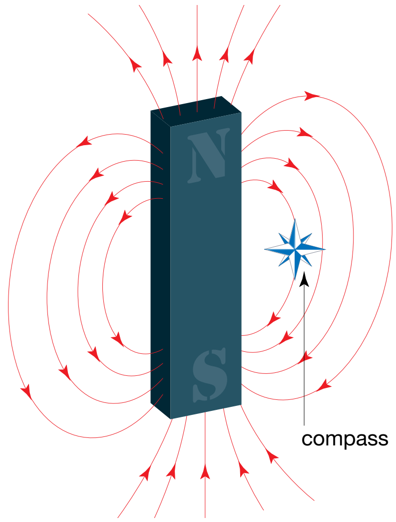


FIGURE 10.39 The magnetic field around a bar magnet. The closeness of the lines indicates the relative strength of the magnetic force, which is strongest at the poles.



10.9.2 Electromagnetism

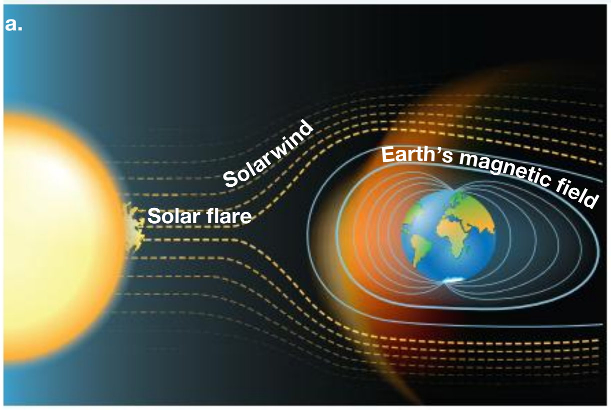
So why are some materials magnetic and other materials not? The answer lies in the electrons. Remember that charges are surrounded by electric fields. When the charges move, the electric fields move. We saw in Topic 9 that changing the electromagnetic field leads to light production. We can detect the magnetic field around a current carrying wire in the same way we detect it around a magnet. Compasses placed around the wire reveal a circular pattern to the magnetic field.

In general, we can say that moving charge makes a magnetic field.

Inside atoms there are moving electrons and so all atoms make magnetic fields to some degree. However, in most materials, the fields cancel each other out. Only in a few materials do we have some leftover magnetic fields. This same effect is what gives the Earth its magnetic field (see Topic 9). Convection of magma inside the Earth results in large 'circuits' of electron flow. This produces the magnetic field that surrounds and protects our planet.

FIGURE 10.40 Without a current the compasses point north, but when the current flows we see evidence of a circular magnetic field.

FIGURE 10.41 a. When charged particles hit the Earth's magnetic field, they experience a force and are deflected safely away rather than coming in and damaging our atmosphere. b. The few particles that get in cause the atmosphere to glow causing the Northern and Southern Lights.



10.9.3 Electromagnets

An **electromagnet** is a temporary magnet consisting of a coil of wire and an iron core. The coil of wire is called a **solenoid**.

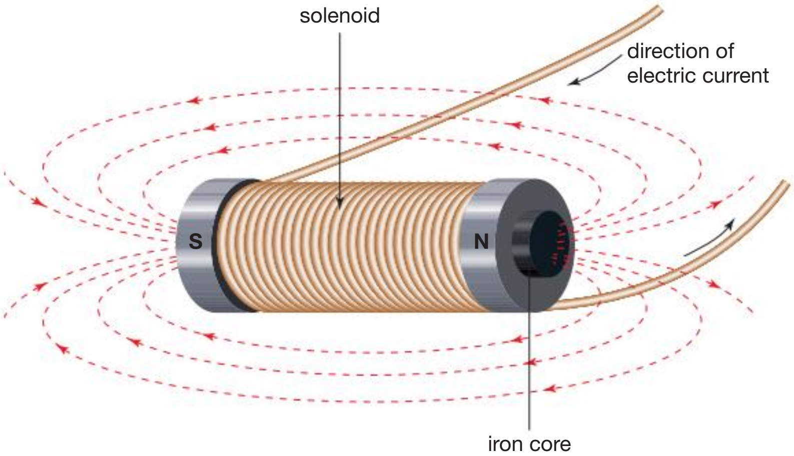
Features of a electromagnets

- A magnetic field is produced in and around the solenoid when electric current flows in the coil, just as we get a magnetic field around a single current carrying wire.
- Without the iron core, a magnetic field would still be created.
- With an iron core, the strength of the magnetic field is increased while the current is flowing.
- One end of a solenoid is a north pole and the other end is a south pole, just like a bar magnet.
- A big advantage of electromagnets over other magnets is that the magnetic field can be turned on or off at the flick of a switch or the push of a button.

electromagnet magnet formed by wrapping a coil of wire around an iron core. When electricity passes through the coil, the iron core becomes an electromagnet.

solenoid coil of wire able to pass a current

FIGURE 10.42 The magnetic field of a solenoid. An iron core inside the solenoid increases the strength of the magnetic field.



elog-0462

INVESTIGATION 10.10

Mapping the magnetic field

Aim

To map the magnetic field around magnets

Materials

- horseshoe magnet in a plastic bag
- overhead transparency
- 2 bar magnets in plastic bags
- iron filings
- sheet of A4 paper
- small compass

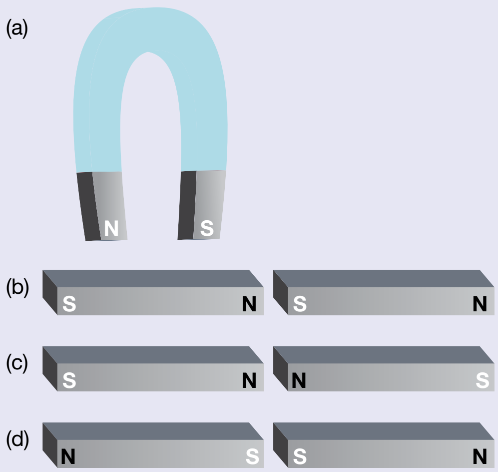
Method

Part A

1. Place a bar magnet in the centre of a sheet of white paper. Cover the paper and magnet with an overhead transparency.
2. Carefully sprinkle iron filings over the transparency, gently tapping it to spread the filings out. Take care not to let iron filings get under the transparency.
3. Place a compass at several positions around the magnet. The direction in which the compass needle points shows the direction of the magnetic field lines.

Part B

4. Use the iron filings to investigate the magnetic fields around a horseshoe magnet and the pairs of magnets shown in the figure.
5. Place a compass at several positions around the magnet/s to determine the direction of the magnetic field lines.



Results

Part A

1. Draw a diagram of the pattern made by the iron filings. Label the north pole and south pole of your magnet on the diagram. The pattern in your diagram is a map of the magnetic field around the bar magnet.
2. After placing the compass at several positions around the magnet, add arrows to your diagram to show the direction of the magnetic field.
3. Do the magnetic field lines run from north pole to south pole or from south pole to north pole?

Part B

4. Draw diagrams of the magnetic fields around the magnet/s in the figure. Indicate the direction of the magnetic field using arrows.

Discussion

1. Where does the magnetic field appear to be strongest? How do you know this?
2. What happens to the strength of the magnetic field as you get further from the magnet?

Conclusion

Write a conclusion for this investigation.

elog-0464

INVESTIGATION 10.11

A look at the field

Aim

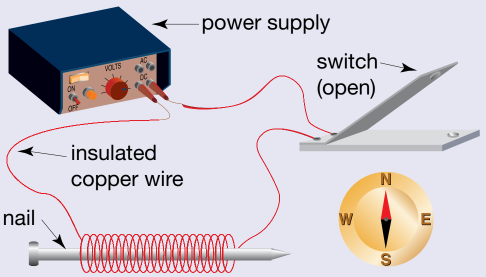
To investigate the magnetic field in and around an electromagnet

Materials

- insulated copper wire
- power supply
- switch
- compass
- large iron nail

Method

Part A



1. Set up the circuit shown in the figure shown. Wind 20 turns of wire around the nail. There will be a lot of wire left over but don't cut it.
2. Set the power supply to two volts.
3. Use the compass to find north and line the nail up so that the sharp end points to the east.
4. Place the compass at the sharp end of the nail as shown in the diagram and close the switch just long enough to observe any change in direction of the compass needle.
5. Place the compass at the blunt end of the nail, close the switch briefly and observe the change in direction of the compass needle.
6. Place the compass beside the nail, close the switch briefly and observe the change in direction of the compass needle.

Part B

7. Reverse the connections to the terminals of the power supply so that the electric current travels in the opposite direction.
8. Repeat your tests with the compass to find which end of the electromagnet is the north pole and which end is the south pole.

Results

1. State whether the sharp end of the nail is the north or south pole of the electromagnet. (Remember that the end of the compass that originally pointed north now points in the direction of the magnetic field.)
2. Draw a diagram of the magnetic field in and around your homemade electromagnet. Label the north and south poles.
3. What happens to the electromagnet when the direction of the electric current is reversed?

Conclusion

What can you conclude about the direction of the magnetic field around an electromagnet?

on Resources

eWorkbook Exploring magnets and magnetic fields (ewbk-4517)

assess on Additional automatically marked question sets

10.9 Exercise

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Select your pathway

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

Remember and understand

1. How is a temporary magnet different from a permanent magnet?
2. What is a magnetic field?
3. Why does a compass needle point north?
4. List some common devices that make use of electromagnets.
5. Explain the difference between an electromagnet and a solenoid.

Apply and analyse

6. What advantage do electromagnets have over other types of magnets?
7. The Magnetic North Pole of the Earth can be considered as one pole of a bar magnet. Is it a south pole or a north pole? Explain your answer.

Evaluate and create

8. Why do you think that an old-fashioned ship's compass was usually built with a brass casing instead of a stronger metal like steel?
9. **SIS** Sketch a magnetic field around a bar magnet. Be careful in drawing the shape to represent how the strength of the field changes and use arrows to show the direction of the field.

Fully worked solutions and sample responses are available in your digital formats.

10.10 The motor effect

LEARNING INTENTION

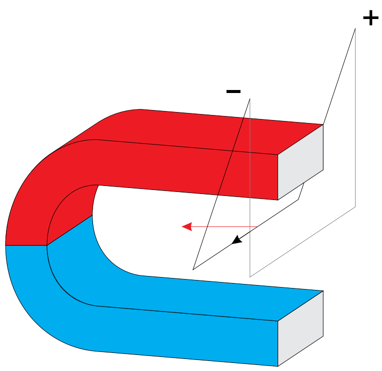
At the end of this subtopic you will understand how a current passing through a magnetic field leads to a force on the current carrying wire. This 'motor effect' is used to make electric motors. You will also understand the function of the parts of a simple motor.

10.10.1 Movement from electricity

The motor effect is the force a wire experiences when it carries a current through a magnetic field. It can be easily observed by placing a wire between the poles of a horseshoe magnet and turning on the current. You will see the wire move. If the current direction or orientation of the magnet is changed, the direction of the force will change. Many devices work on the principle of the motor effect.

The motor effect is the name given to the force that a wire experiences when it carries a current through a magnetic field. An electric motor is any device that converts electrical energy into kinetic energy.

FIGURE 10.43 Demonstrating the motor effect



10.10.2 Motors

What do a hair dryer, a food processor, a clothes dryer and an electric drill all have in common? The obvious answer is that they all use electrical energy. Another thing that these appliances have in common is an **electric motor**.

FIGURE 10.44 An electric motor converts electrical energy into kinetic energy. This conversion can only take place because of the magnetic effects of electric current.

Step by step … how a motor works

- An electric motor contains coils of wire surrounded by two or more magnets.
- The coil produces a magnetic field when electric current flows through it.
- There is a motor effect when this field interacts with the field of the magnets that surrounds the coil.
- One side of the coil is pushed down and the other side is pushed up.
- The coil rotates.

DISCUSSION

Motors make things rotate. How did we perform this function before motors? Give some examples.

Parts of a DC electric motor

The electric current supplied by a cell or battery is called direct current (DC). It flows in one direction only. The electric current provided to your home by power stations is called alternating current (AC), which reverses direction multiple times per second. Small motors usually work using DC (figure 10.45).

- The **armature** is the turning part of the motor on which coils of wire are wound. The coils are called rotor coils because they cause the armature to rotate.
- When electric current flows through the **rotor coils**, a magnetic field is produced. The magnetic field produced by these coils interacts with the magnetic field produced by the field magnets.
- The **field magnets** are permanent magnets that do not move. In larger commercial motors they are replaced with a separate coil (called a field coil), which provides a stationary electromagnet.
- The **brushes** are connected to the power supply and lightly touch the commutator as the armature turns. This allows current to travel through the rotor coils.
- The **shaft** is part of the motor that is attached to the device the motor is turning, like a fan or gear wheel. As the armature turns, the shaft turns.
- As each rotor coil turns through 180 degrees to face the opposite field magnet, the force on it would change direction, turning it back the other way. The **commutator** consists of a split metal ring. As the armature turns, the commutator turns with it while the brushes remain still. When the armature has turned through 180 degrees, the opposite side of the commutator makes contact with the brush connected to the positive terminal of the power supply. The direction of the current in each rotor coil reverses. This allows the armature to keep rotating in the same direction, rather than spinning first one way, then the other. Alternating current motors don't need a commutator as the current reverses itself as the motor rotates.

electric motor device that converts electrical energy into kinetic energy of a rotating shaft

armature the turning part of an electric motor on which coils of wire are wound

rotor coils coils of a motor that turn when a current flows through them

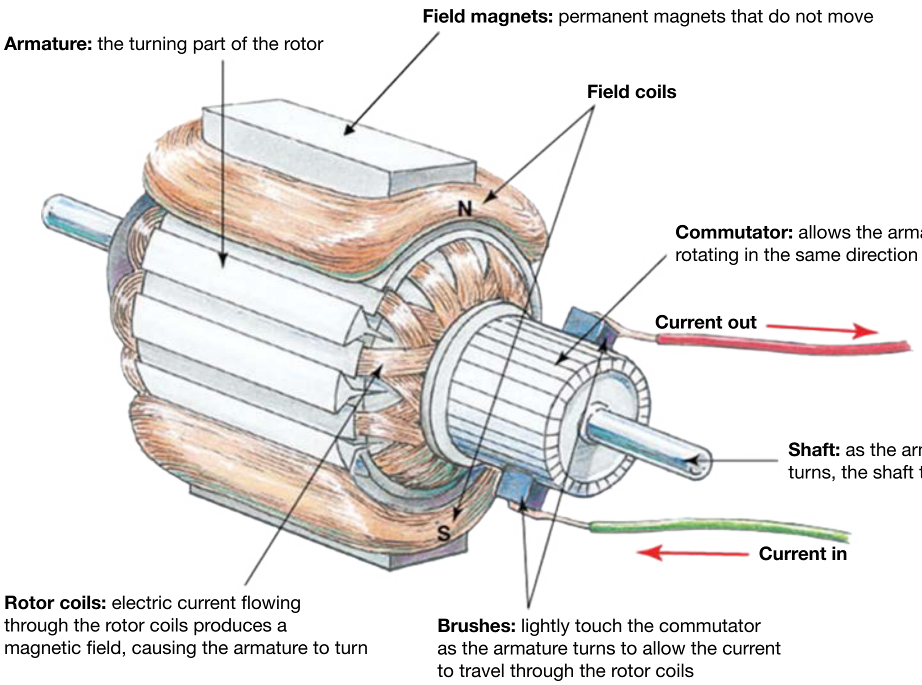
field magnets magnets producing a magnetic field that acts on the rotor coils

brushes part of an electric motor that allows current to travel through the rotor coils by being connected to the power supply and lightly touching the commutator

shaft central rotating rod of the motor that transmits the kinetic energy

commutator device attached to the rotor shaft that receives the current. In most motors it is a metal ring split into sections.

FIGURE 10.45 A commercial DC motor

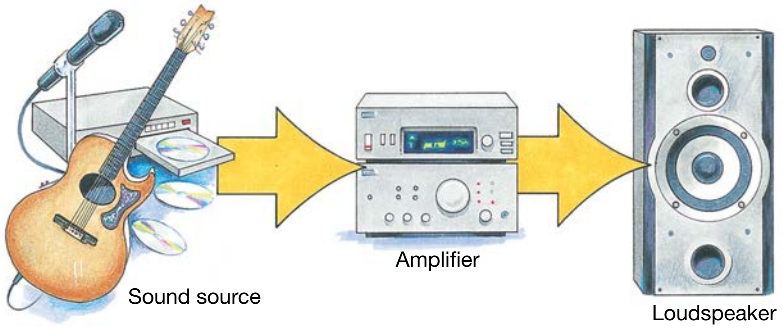


10.10.3 Producing sound through a loudspeaker

Microphones, telephones, radios and television sets produce changing electric currents. These changing currents are so small that they need to be amplified before being sent to a loudspeaker.

As a coil of wire carrying electric current produces a magnetic field, it is not surprising that the same coil of wire moves when it is in the region of another magnet. Just as two magnets attract or repel each other, the coil can be attracted to or repelled by a magnet. Loudspeakers rely on this interaction to convert the changing electric currents into the kinetic energy of vibrating air that allows you to hear sound.

FIGURE 10.46 The process of producing or reproducing sound through a loudspeaker



Inside a speaker

Inside a speaker, the electric current flows through the copper wire coil that is tightly wound around the base of the cone. The coil, known as the **voice coil**, and the base of the cone sit inside a cylindrical permanent magnet. Like any solenoid with electric current flowing through it, the coil produces its own magnetic field. However, in a speaker the electric current is rapidly changing direction. The coil moves backwards and forwards as it is alternately repelled and attracted to the base of the cylindrical magnet. The cone of the speaker, also known as the **diaphragm**, vibrates as the coil moves, causing the air nearby to vibrate and so producing sound.

voice coil coil of wire in a loudspeaker that vibrates at the frequency of the electrical signal. This frequency matches the frequency of the sound produced by the cone.

diaphragm cone of a loudspeaker that vibrates to produce a sound wave

Resources

Video elesson Vibration of a speaker diaphragm (eles-2675)

assess on Additional automatically marked question sets

10.10 Exercise

learn on

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Select your pathway

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

Remember and understand

1. Into what form of energy do motors convert electrical energy? How does this differ from the energy transformations in microphones and speakers?
2. Explain the difference between AC and DC.
3. Construct a table to group all the parts of an electric motor into 'moving' and 'non-moving' parts.

Apply and analysis

4. What is the role of a permanent magnet in a loud speaker?
5. Explain why the voice coil in a speaker is attached to the cone.
6. Why doesn't an AC motor need a commutator?

Evaluate and create

7. Imagine you were advertising in the employment pages of a newspaper for the parts of a DC electric motor. Write a job description for each part.

Fully worked solutions and sample responses are available in your digital formats.

10.11 Generators

LEARNING INTENTION

At the end of this subtopic you will understand that when a coil moves relative to a magnetic field, a voltage is generated across the coil. You will be able to explain how we use this process to provide electrical power to the nation.

DISCUSSION

Drop a powerful, but small, magnet down a meter long copper tube. Discuss what happens and why. What does this have to do with modern car brakes?

10.11.1 AC or DC?

The **alternating current** (AC) flowing from an AC generator changes direction after every half turn. It changes direction about 100 times every second. Alternating current is the type of electricity produced by power stations and delivered to our homes. In household lights and appliances, electrical energy is transformed into other forms of energy as electrons move backwards and forwards.

alternating current current that changes direction along a wire a number of times per second

Direct current (DC) is produced by batteries or in a DC generator. In DC the electric current flows in one direction only.

Alternating current, rather than direct current, is supplied by power stations because it is easier and cheaper to generate. It is also easier and cheaper to distribute widely over large distances. In Australia, electricity is supplied to homes at a voltage of 240 volts.

SCIENCE AS A HUMAN ENDEAVOUR: The war of the currents

In the late 1880s, Thomas Edison and Nikola Tesla were engaged in what is now known as the War of the Currents. Edison, the rich all-American businessman developed DC and took an early lead in producing it for New Yorkers. However, there was a problem in that DC is not easily converted to higher or lower voltages. Tesla, a maverick inventor along with his business partner George Westinghouse, developed AC generators, which easily converted voltages using a transformer.

Edison, fearing that he would lose money, tried to discredit his opponents and AC. He spread 'fake news' saying that AC was far more dangerous than DC. Ever the showman, Edison publicly electrocuted stray animals just to prove his point. On one occasion he even electrocuted an elephant.

FIGURE 10.47 Edison and Tesla and the War of the Currents

The Chicago World's Fair, in 1893, was an event meant to highlight the newest of technologies. General Electric offered to power the fair using Edison's DC for $554 000, but lost to Westinghouse, who charged only $399 000 to use Tesla's AC. Alternating current has been the standard to this day. Tesla's legacy is still influential to this day. You may know of the company Tesla, which Elon Musk named in honour of Nikola Tesla.

10.11.2 How a generator works

In a motor, electrical energy is converted into kinetic energy. A generator works like a motor in reverse. Kinetic energy is converted into electrical energy.

- A wire or coil cuts through a magnetic field. This can be the wire moving or the magnet moving, it doesn't matter.
- The electrons in the wire feel a push along the wire from the magnetic field. We say that a voltage has been induced. The process is called **induction** (figure 10.48).
- If the wire or coil is in a circuit a current will flow.

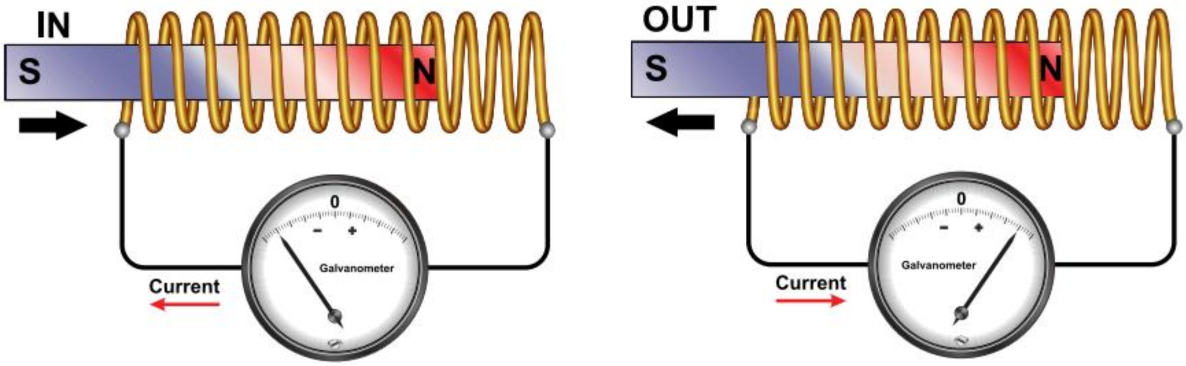
induction a process where the electrical or magnetic properties of an object produces similar properties in a nearby object without physical contact; for example, the production of a current by repeatedly moving a magnet in and out of a coil

Increasing the current

The size of the electric current produced by a generator can be made larger by increasing:

- the number of turns of wire in the coil
- the strength of the magnet
- the speed of the relative movement between the coil and the magnetic field.

FIGURE 10.48 A magnet is pushed into a coil of wire. A voltage is induced in the coil causing a current to flow. When the magnet is removed, current flows in the other direction. Repeat the process and alternating current is produced.



Phone talk

Your telephone handset or mobile phone has two parts: a speaker and a microphone. When you have a conversation on a telephone, a microphone in the mouthpiece converts sound into electrical energy so that a signal can be sent to the other telephone. A speaker in the earpiece converts the electrical energy received from the other telephone into sound energy.

The mouthpiece of a telephone handset contains a small metal plate (the diaphragm), which vibrates when you speak. A crystal beneath the diaphragm gets pushed out of shape when the diaphragm vibrates. The electric current flowing from the microphone changes with the shape of the crystal.

The earpiece of a telephone handset contains a speaker. It consists of a permanent magnet, a voice coil wound around a soft iron core and a plastic disc (the diaphragm). The plastic disc is pulled backwards and forwards by the iron core in the voice coil as the electric current in the coil changes.

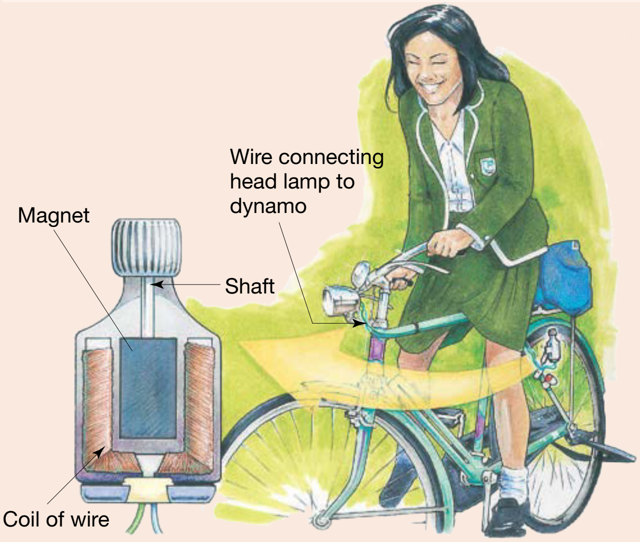
FIGURE 10.49 Phones use induction to convert sound energy into electrical energy, then convert the electrical energy back to sound energy via a speaker.

SCIENCE AS A HUMAN ENDEAVOUR: Dynamo!

Michael Faraday generated an electric current by moving a coil of wire through a magnetic field (see section 10.9.1). Devices that use this principle are known as dynamos. You may have ridden a bike with a dynamo attached to make a headlamp glow — or even with a blender attached to make a smoothie! A bicycle dynamo generates electricity to keep a headlamp glowing without the need for a battery. As the wheel turns, a magnet spins inside a stationary coil of wire. The relative movement between the magnetic field and the coil results in an electric current in the coil that powers the headlamp.

Like the bicycle dynamo, a car generator generates an alternating current. Although it looks very much like an electric motor, instead of converting electrical energy to kinetic energy, it converts kinetic energy into electrical energy. Each slip ring is connected to one end of each coil of wire.

FIGURE 10.50 A bicycle dynamo — the moving wheel spins a magnet inside a coil of wire to produce an electric current.



Resources

Interactivity Magnetic flux and Lenz's law (int-0050)

10.11.3 Mains power generation

The method used to generate the electricity used in your home, school or workplace is not very different from that used by a single hand-operated generator or bicycle dynamo. Of course, the scale is very much larger.

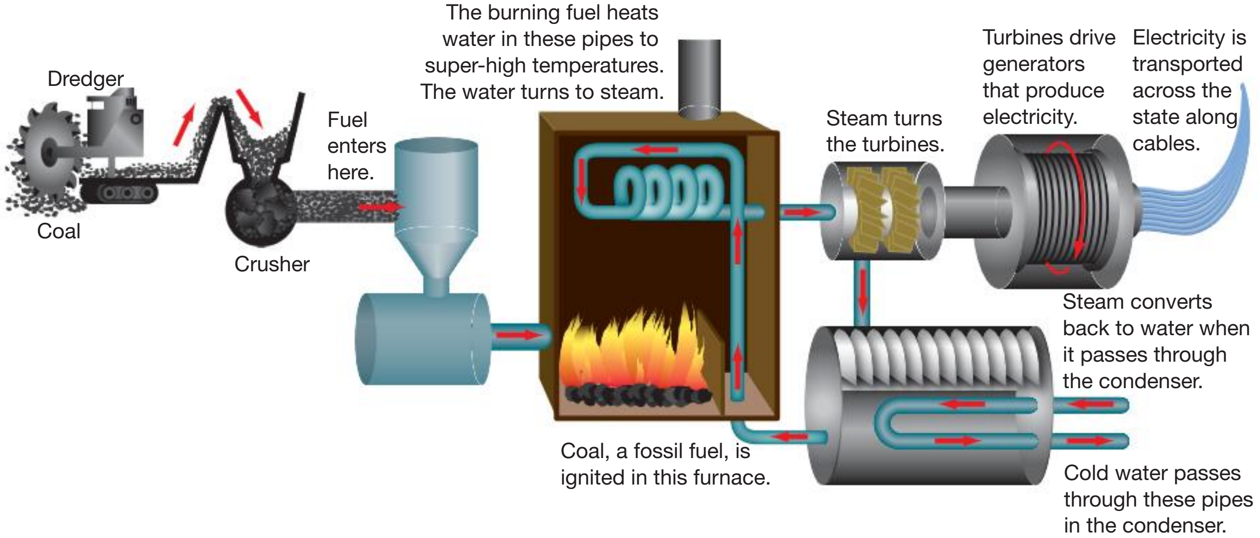
Power generation from fossil fuels

In coal-fired power stations electrical energy is transformed from the chemical energy stored in coal. The same is true for oil and gas power stations. Oil, coal and gas are collectively known as fossil fuels as they are the remains of long-dead plants and micro-organisms. In all fossil-fuelled power stations the energy production process is as follows.

- Chemical energy in the fuel is released as heat and light energy by combustion (burning).
- Heat energy is transferred to water, which produces steam.
- Steam is under pressure and the temperature is up to 400 °C. It hits a turbine (fan-like blades) at high velocity.
- Heat energy of the steam is converted to kinetic energy of the turbine.
- The turbine is connected to the coils in a generator. The coils rotate rapidly inside huge electromagnets.
- The motion of the coils in the magnetic field produces a large voltage.
- When the generator is connected to a load a large electric current flows.

In 2019, about 76 per cent of Australia's electrical energy was generated by coal-fired power stations. Most of the remaining 24 per cent was provided by renewable energy, which is increasing year on year.

FIGURE 10.51 The energy production process in a coal-fired power station



Power generation from other sources

There are many ways to turn a turbine that do not require the burning of fossil fuels.

- In nuclear power stations the energy required to boil water to produce the steam that turns the turbine blades is released in nuclear reactions.
- In hydroelectric power stations the energy used to turn the turbines is transformed from gravitational potential energy. Water falling from a great height turns the turbines directly with no need for high-pressure steam.
- Wind power directly transforms kinetic energy in the wind into rotation of the turbine.
- Wave power uses waves to compress columns of air in tubes, which turns small turbines.
- Geothermal power uses steam produced by pumping water into a hole drilled into the ground in geologically active areas. The heat of the rocks deep underground boils the water with no need for fuel.

FIGURE 10.52 The generation of household electricity in power plants and by wind turbines depends on the close relationship between electricity and magnetism.

elog-0466

INVESTIGATION 10.12

Electrical energy from kinetic energy

Aim

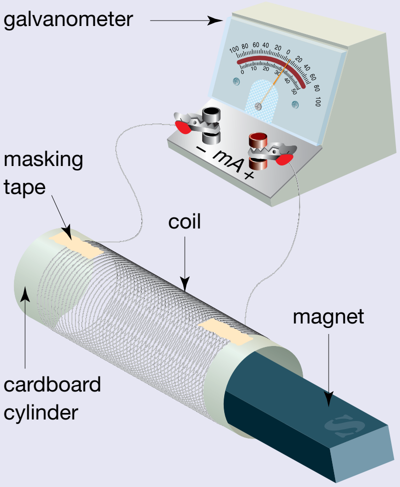
To investigate the generation of electric current by the movement of a magnet inside a coil of wire

Materials

- 2 bar magnets (one large, one small)
- length of insulated copper wire
- cardboard tube
- masking tape
- galvanometer
- large iron nail

Method

1. Make a solenoid by winding the insulated copper wire evenly around the cardboard tube. Tape the wire down so that it cannot unwind itself. Connect the free ends of the wire to the galvanometer.
2. Place the smaller magnet inside the solenoid so that the end you are holding is just inside the cardboard tube.
3. A galvanometer is used to detect and measure small electric currents. Record the reading on the galvanometer while the magnet is inside the solenoid.
4. Watch the needle on the galvanometer while you rapidly pull the magnet out of the solenoid. Record your observations.
5. Watch the galvanometer needle while you rapidly push the magnet back into the solenoid. Record your observations.
6. Predict which way the needle of the galvanometer will move if the magnet is reversed and pulled out of the solenoid and then pushed into the solenoid. Test your predictions.
7. Move the magnet quickly and slowly out of the solenoid and observe any changes to the current.
8. Replace the magnet with a larger magnet and record any differences to the current.



Results

1. What was the reading on the galvanometer when the magnet was inside the solenoid?
2. What was the reading on the galvanometer when the magnet was outside the solenoid?
3. What did you observe when the magnet was rapidly pushed into and pulled out of the solenoid?
4. When the magnet was reversed, were your predictions about the galvanometer reading correct?
5. How is the current affected if the magnet is moved into or out of the solenoid faster?
6. How is the current affected if a larger magnet is used?
7. Does pulling the solenoid away from the magnet have the same effect as pulling the magnet away from the solenoid?

Discussion

1. Does a stationary magnetic field inside a solenoid produce an electric current in the solenoid?
2. Does a moving magnetic field inside a solenoid produce an electric current in the solenoid?

Conclusion

What can you conclude about moving magnetic fields and electric currents?

10.11.4 Electricity in the home

DISCUSSION

Imagine that you are at work in a large building. Suddenly the alarm goes off. There is a fire! Smoke is billowing through the corridors. You crawl on your hands and knees to stay out of the smoke, but you cannot see where you are going because your eyes are stinging. You use one hand to feel the wall, reasoning that you will be able to escape by touch. Why are you at risk of electrocution? What could you do to improve your chance of survival?

It's in the box

The electric cable that carries alternating current to your home holds two wires. For electricity to flow from a power point in your house, two switches need to be closed:

- The **main switch** in your home's meter box needs to be closed for electric current to flow through these wires.
- The power point switch needs to be closed.

main switch control switch that turns all the household circuits on or off

Two or three pins?

Power points have three sockets. When you plug in an electrical device and switch on the power, alternating current flows between the top two sockets through the appliance. The third socket, called the **earth socket**, is connected to a metal pipe in the ground.

If an electrical appliance has an uninsulated metal casing, its plug has three pins. The bottom pin is connected by a wire to the metal casing. This pin fits into the earth socket. If there is a fault in the appliance, and the metal casing becomes 'live', electric current flows to the ground, rather than through the body of a person touching the metal. Appliances with two-pin plugs are 'double insulated' to make them safe. Any metal on the outside of these appliances is insulated with plastic. This prevents electric current from flowing from the metal to the wiring inside.

FIGURE 10.53 Devices with uninsulated metal casings have three pins; two-pin devices are double insulated.

Transformers

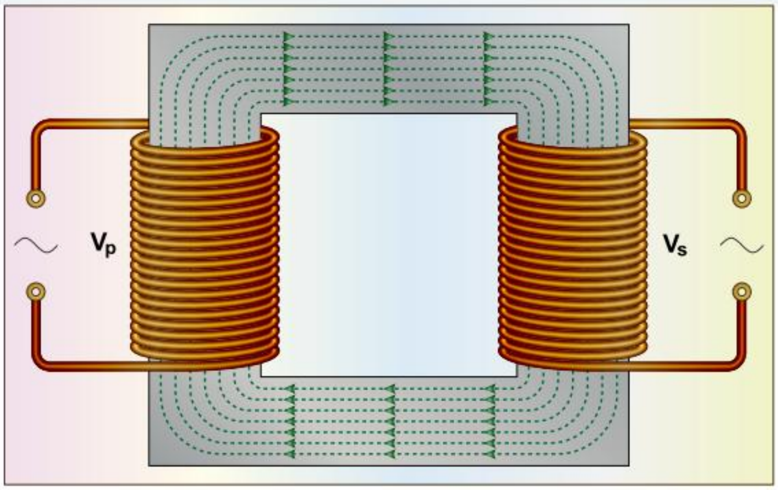
Another device invented by Faraday was the **transformer**. This device uses the changing magnetic field of one coil to induce a voltage in a second coil. By changing the ratio of the turns you can change the voltage of the electricity.

- At power stations we increase the voltage to transmit the electricity more efficiently over long distances.
- Near your home there will be a transformer that drops the voltage to a level that will not create large dangerous sparks when you plug in electrical devices.
- You may have electronic devices that need a lower voltage to work safely. For example, devices such as computer printers and electronic games require voltages of 9 volts or 12 volts. A transformer, usually attached to the lead, is plugged into the power point. The transformer reduces the voltage from 240 volts to the 9 volts or 12 volts required.

earth socket connection that provides a route for current to flow to the ground when an electrical appliance malfunctions

transformer device that can increase or decrease voltages for alternating current

FIGURE 10.54 The primary coil on the left is connected to an AC supply that needs converting to a different voltage. The changing magnetic field of the primary coil keeps growing and shrinking and therefore cutting through the secondary coil. This induces a voltage in the secondary coil. By changing the number of turns on the coils you can control the size of the voltage on the secondary coil.



Some devices use DC current; you may have noticed a black box on your mobile phone or laptop charger — this contains the transformer that 'steps down' the voltage, and another circuit, called a **rectifier**, uses diodes to change the alternating current into direct current.

FIGURE 10.55 Some electrical devices require less than the 240 volts supplied by power points. A transformer is used to 'step down' the voltage.

Dangers of electricity

The 240-volt AC household power supply can kill. If you tamper with working appliances or electrical wiring, it is possible that electric current will flow through your body. Electrocution — death from electric shock — can be caused by electric currents as low as 0.05 amperes flowing through your body.

The current can cause severe burns or potentially affect the way your heart beats.

One of the biggest causes of electrocution in the home is the use of damaged cords and plugs. If appliance cords and plugs are frayed or damaged, exposing the smaller plastic covered wires inside, the appliance should be replaced or taken to a qualified repairer.

rectifier device that changes alternating current to direct current

The bathroom can be a very dangerous place in which to use electrical appliances. Tap water contains charged particles (ions) due to substances dissolved in it. It is therefore a good conductor of electric current. Appliances like hair dryers, radiators and electric shavers should never be used when there is water in the basin or bath, or when there is water on the floor. If a working appliance was to fall into some water, you could be electrocuted if you came in contact with the appliance, either by accidentally touching it or by trying to pick it up.

SCIENCE AS A HUMAN ENDEAVOUR: The defibrillator

If a current flows across your heart then your heartbeat may be altered. The heart beats regularly due to electrical impulses provided by nerve bundles on the heart. A large current can lead them to pulse irregularly leaving your heart in a fluctuating and ineffective state, which can quickly lead to death. This is similar to some forms of heart attack and is called **fibrillation**. A **defibrillator** is a machine that delivers a controlled electric shock across the heart, which can reset the electrical pulses and return the heart to normal function.

FIGURE 10.56 Many workplaces now keep a defibrillator on site as part of their first aid equipment.

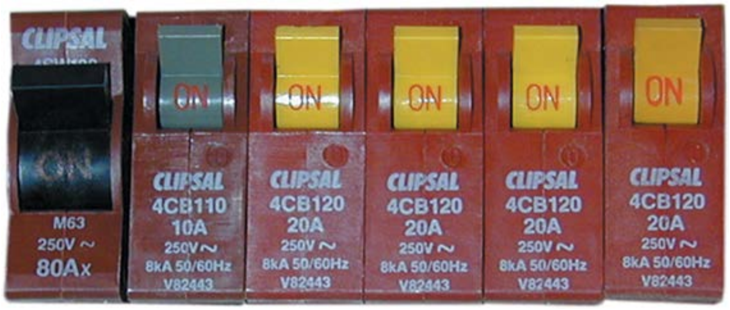
fibrillation rapid twitching of the heart muscle, which disrupts its rhythm; can cause heart attacks

defibrillator a device that delivers a large electric shock to the heart in an attempt to reset its rhythm back to a regular pulse

Electrical safety

The appliances and lights in your home are all connected in parallel. There are normally two separate parallel circuits in a house, one for the lights and one for the power points. If too many appliances or lights are turned on at once, the total current is too large and a **fuse** or **circuit breaker** can open the main circuit and stop the flow of current. A set of fuses or circuit breakers can be found in your meter box at home. A fuse is a short piece of wire that melts if the current gets too high. A circuit breaker is a special switch that opens automatically if the electric current gets too high.

FIGURE 10.57 The switch on the left is a safety switch. The other switches are circuit breakers.



While fuses and circuit breakers open circuits before they overheat, they do not work quickly enough to stop people from getting an electric shock if a short circuit causes a dangerously high current. Safety switches (also known as **residual current devices**) can turn off the power much more quickly — in less than one-thirteenth of a heartbeat — thus reducing the risk of death due to electric shock in the home.

fuse safety wire that melts when too much current flows through it. Fuse wires are designed to melt at different currents.

circuit breaker safety device that breaks a circuit if the current suddenly exceeds a specified size

residual current devices a form of safety switch that can quickly detect a possible fault and break the flow of electricity in a circuit in order to prevent electrocution

on Resources

Interactivity Circuit breakers (int-5777)

assesson Additional automatically marked question sets

10.11 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 7, 11	Questions 4, 5, 8, 10, 12, 14	Questions 6, 9, 13, 15, 16, 17

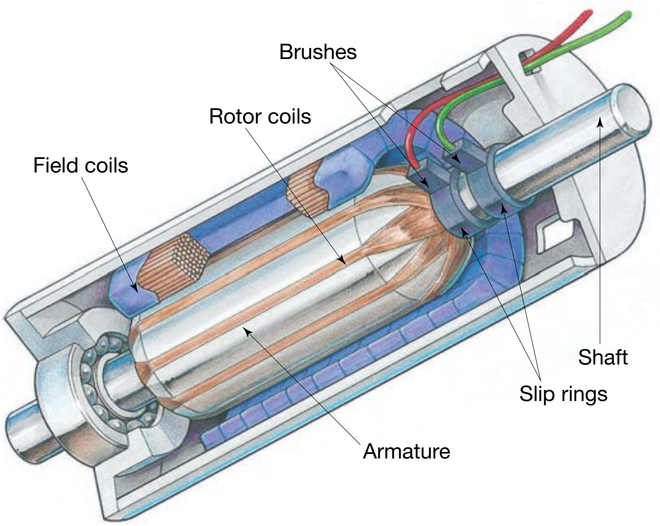
Remember and understand

1. How did Michael Faraday generate an electric current?
2. What is the role of the turbines in a power station?
3. What should be done when appliance cords or plugs become frayed or damaged?
4. Why does extra care need to be taken when using electrical appliances in the bathroom?
5. What drives the turbines in:
   a. a coal-fired power station
   b. a nuclear power station
   c. a hydroelectric power station?

6. From which forms of energy (not just the initial form) is electrical energy converted in:
   a. a coal-fired power station
   b. a hydroelectric power station?
7. Why do power points have three sockets even though many appliances have plugs with only two pins?
8. Explain why devices like electronic games and computer printers have heavy transformers attached to their leads or plugs.
9. Describe what transformers do at the power station and near your home. What feature of the design allows this to happen?
10. What changes can be made to a dynamo to increase the size of the electric current generated?
11. How is the electric current produced by an AC generator different from the electric current produced by a DC generator?

Apply and analyse

12. How is the generation of electricity in a power station similar to the generation of electricity by a hand-operated generator or bicycle dynamo?
13. Examine the diagram below of the AC car generator.



   a. How is the AC generator similar to an electric motor?
   b. Describe the differences between an AC generator and a DC motor.
   c. The electric generator is sometimes described as the reverse of an electric motor. Explain why.
14. Not all of the chemical energy stored in coal is transformed into useful electrical energy in the home. List the ways in which energy is wasted from the time it is burned up until the time that it is used to light a room at night.
15. The speakers used in some fast food 'drive thru's' also act as microphones. They contain a permanent magnet, a voice coil and a diaphragm just as normal speakers do. Explain how it might be possible to use the speaker to change sound energy into electrical energy.
16. a. What important roles do both fuses and circuit breakers play?
   b. Explain how circuit breakers are different from fuses.

Evaluate and create

17. SIS Touching a circuit and having a current flow through you can be painful or even deadly. If you are lucky, you are able to let go of a wire before you suffer too much damage. Unfortunately, beyond a certain current you cannot let go. This current is known as the 'let go' current. The size of the let go current has been found to vary with the frequency of the current as shown in the table.
   a. Plot the data in a graph and connect the points to show a curve representing the let go current across a range of frequencies.
   b. What is the main frequency in Australia?
   c. Look at your graph and comment on your findings in light of your answer to part b.

TABLE Size of let go current according to frequency

Frequency (Hz)	Let go current (mA)
5	25
10	17
25	14
50	13
75	14
100	15
125	16
150	18

Fully worked solutions and sample responses are available in your digital formats.

10.12 The future of electricity

LEARNING INTENTION

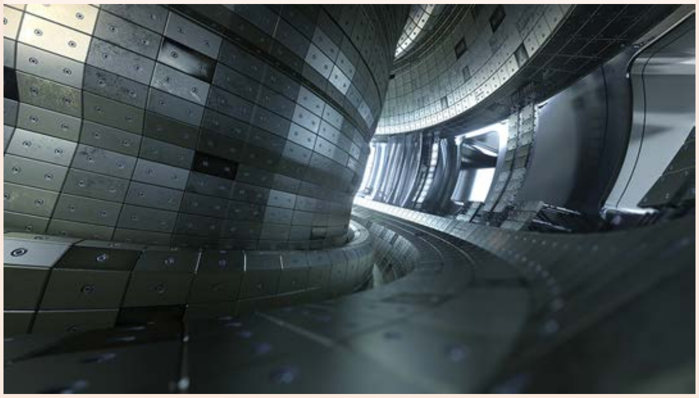
At the end of this subtopic you will understand how developments in electricity generation and electronic capabilities will affect your life.

10.12.1 Changing times: Power

SCIENCE AS A HUMAN ENDEAVOUR: The future of electricity

As discussed in topic 9, our world is heating. We are at a point where, as a society, we need to re-think how we produce our electricity. There are non-polluting options for turning a generator as discussed in section 10.11.3. Solar panels convert sunlight directly into electricity without any need to boil water in the process. These can be a particularly attractive option in countries with a lot of sunlight.

FIGURE 10.58 A tokamak fusion reactor. Powerful magnetic fields hold a superheated gas called a plasma. The magnetic field causes heating in the plasma that can produce collisions between atoms that fuse together to release energy.



Nuclear fusion — Power of the future?

Nations across the world are racing to produce electricity in the same way as the Sun — nuclear fusion. Unlike in a nuclear fission reactor in which heavy elements break apart releasing energy, in fusion power lighter elements are fused to make heavier ones. Unlike fission, this process produces little radioactive waste and cannot under any circumstance undergo a nuclear meltdown, a catastrophic process that has led to a number of radioactive disasters. Electricity from fusion may well be the power of the future, but we are quite a long way from producing it in large quantities.

10.12.2 Changing times: How small can we go?

Electronics have been getting smaller and smaller over the years. This has enabled us to pack more powerful computational abilities into smaller packages. Transistors have been getting smaller year on year to the point that the record at the time of writing is the size of 1 nano-metre (a billionth of a metre).

This record was set in the laboratory and is not ready for using in industry, but the smallest design currently in use is only 5 nano-metres in size.

Unfortunately we are approaching a limit to this ability to go smaller and smaller. If electronic components continue to get smaller then they will no longer be able to contain their electrons! When wires are packed so small, electrons start to behave strangely and can actually jump between wires making them useless as we no longer know whether a circuit should be on or not. If we intend to keep on making smaller and more powerful computers we will need a way of transmitting information that doesn't rely on electrons. Engineers are already hard at work on optical processors that use light instead.

10.12.3 Changing times: How smart can we go?

In 1975 the CEO of Intel, Gordon Moore, noticed a doubling every two years in the number of transistors on an integrated circuit. He predicted that this rate of growth would continue for at least another decade. Forty-five years later and Moore's law continues to hold true, though it may come to an end soon if we cannot continue to shrink our transistors.

FIGURE 10.59 Will AI replace us or allow us to do more interesting jobs in greater safety? Only time will tell.

While some scientists believe that we may one day be able to achieve intelligence in robots by producing a sufficiently powerful processor, all attempts to produce a brain simulation have so far failed. We simply do not know enough about how the brain works to simulate it in any meaningful way. For now our devices are becoming 'smart' by using artificial intelligence (AI). This is not true intelligence as we know it. Artificial intelligence software has seen a huge development in recent times that allows the smart device to simply connect to large databases of information and looks for patterns. This will have some serious effects on our society as many jobs become more efficiently performed by machines that always make optimal decisions at speeds faster than a human can. Imagine a surgeon that can compare the operation they're currently performing to recordings of every other similar operation instantaneously and adjust their technique accordingly. A robotic surgeon that never gets tired, never twitches and can perform multiple operations per day could ultimately replace the human alternative. How many other jobs may soon be replaced by the rise of AI?

DISCUSSION

Would you trust a robotic doctor to carry out an operation on you? Would you trust a robotic driver? Should we have fully autonomous robotic drones, ships and even soldiers?

10.12.4 Changing times: The car of the future

What sort of car do you expect to be driving 30 years from now? Will it be just a newer, sleeker, lighter version of the cars you see on the road today? How much will petrol cost: $2 per litre or $20 per litre? Most medium-sized cars have petrol tanks that hold between 50 and 80 litres. How much will it cost to fill the tank? Will you have trouble breathing the polluted air in traffic-clogged cities?

It is unlikely that you will be driving a car with an engine powered by petrol. There are several reasons for this.

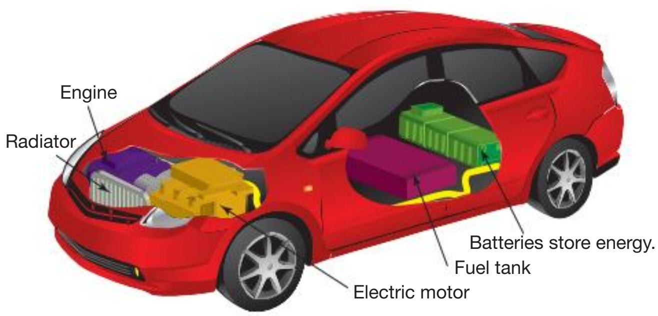
- Petrol is made from oil and the world's oil supply is rapidly decreasing. At the same time, the amount of oil being used is increasing. It has been predicted that the world's oil reserves will run out in less than 50 years.
- Petrol is becoming more expensive. This is partly due to attempts by politicians to conserve the world's oil reserves. As the cost of petrol increases, alternative fuels become more attractive. LPG Liquefied petroleum gas (LPG) is already increasing in popularity as a fuel for cars.
- Petrol-driven car engines cause air pollution. Gases released from car exhausts include carbon monoxide (a poisonous gas), carbon dioxide (a greenhouse gas that contributes hugely to climate change) and nitrogen oxides (which lead to smog and acid rain).

FIGURE 10.60 The Tesla Roadster is a high-performance electric car now available in Australia. It can accelerate from 0 to 100 km/h in 2.1 seconds, has a top speed of 400 km/h and can travel 1000 km before the batteries need recharging.

The hybrid car

The hybrid car combines a bank of rechargeable batteries with a small petrol engine. It provides most of the benefits of a totally electric car. In figure 10.61 the petrol engine of the car generates energy to recharge the batteries while the car is being driven. In some hybrid cars, the petrol engine is connected directly to the motor that turns the wheels. This means that less energy is required from the batteries. The exhaust fumes of hybrid cars still contribute to air pollution, but to a much lesser extent than current petrol-driven cars.

FIGURE 10.61 A hybrid car combines a bank of rechargeable batteries with a small petrol-driven engine.



Hybrid cars, such as Toyota's Prius and Camry, are gaining popularity in Australia as the increased price of petrol puts pressure on car owners to use less of it. Hybrid-car manufacturers are struggling to keep up with demand.

In Australia, the CSIRO is working with car manufacturers to produce lighter and more compact lead–acid batteries that will require less frequent recharging.

CASE STUDY: Battery-powered cars are not new!

Battery-powered electric cars are not new. In fact, before 1900 there were more electric cars than petrol-driven cars. However, petrol-driven cars were more powerful and could travel for longer distances without having to stop. Using petrol was also cheaper than replacing and recharging batteries. By 1930, electric cars had been replaced almost entirely by petrol-driven cars.

FIGURE 10.62 An early electric car

Electric cars

One of the most attractive alternatives to the petrol-driven car is a car powered by rechargeable batteries. Electrical energy from the batteries is used to drive a motor that turns the wheels. The batteries can be recharged while the driver is at home or at work.

Electric cars have four main benefits.

1. Their use will reduce the demand for oil. The world's oil reserves will last longer.
2. They do not release exhaust gases. This would reduce air pollution in large cities.
3. They are very quiet.
4. They are less expensive to run and are easier to maintain as the engine is less complex.

An additional benefit is that electric cars can be designed so that their batteries can be fully or partially charged by solar energy.

There are also some drawbacks to electric cars.

1. Standard electric cars can travel only about 400 kilometres (100–200 km for smaller vehicles) before the batteries need recharging. A tank of petrol would allow most cars to travel 500–800 km before refuelling.
2. Recharging times are longer than refuelling times for petrol cars.
3. The batteries, which are very expensive, typically need replacing after 10 years.
4. Electric cars are more expensive to buy than petrol-driven cars.
5. If everyone owned electric cars, power stations would need to supply more energy for recharging batteries from power points. Although air pollution in cities would be reduced, the air pollution around the power stations would be increased.

Solving the problems

Some of the disadvantages of electric cars will be overcome as the need to replace petrol-driven cars becomes more urgent.

- Automotive engineers are using scientific knowledge, together with computer techniques and models, to design lighter cars. They are also designing car bodies and tyres to reduce the friction caused by the air and road surfaces. These changes will reduce the amount of energy needed to keep cars running. Batteries will last longer.
- Electric cars use batteries that take a long time to charge and are quite heavy. Lighter, smaller and more powerful batteries that charge more quickly are currently being developed.
- As more electric cars are made, the cost of each car will decrease. Also, as petrol becomes more expensive, the higher cost of electric cars will be less of a problem.

New car designs, better batteries and decreasing costs make electric cars a very likely alternative to petrol-driven cars.

on Resources

Video eLesson The Australian-International Model Solar Challenge (eles-0068)

assess on Additional automatically marked question sets

10.12 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. List three benefits of electric cars.
2. State five disadvantages of electric cars at the current time.
3. What is a hybrid car?
4. Why are electric cars likely to become popular after being ignored for over 60 years?
5. Which disadvantages of electric cars do hybrid cars partially or entirely overcome?

Apply and analyse

6. Advertisements for hybrid cars highlight their advantages and sometimes make claims without evidence.
   a. List some disadvantages of hybrid cars.
   b. What type of evidence would you expect from automotive engineers before purchasing a hybrid vehicle?
7. Do you think the government should force car manufacturers to stop making petrol-driven cars and replace them with electric or hybrid cars? State reasons for your opinion.
8. Explain the advances that are being made that allow modern computers and robotic technology to carry out the functions that they do.

Evaluate and create

9. SIS The table shows the number of transistors (in millions) on a graphics chip from a leading manufacturer over a period from 1995 to 2001.
   a. Plot a graph showing the data.
   b. Evaluate the data. Does the data agree with Moore's law?
   c. Explain what the limit will be to Moore's law.

TABLE Number of transistors available on graphics chips per year

Year	Transistors on chip (millions)
1995	2
1996	3.5
1997	7
1998	15
1999	17
2000	25
2001	30

Fully worked solutions and sample responses are available in your digital formats.

10.13 Thinking tools — Flow charts

10.13.1 Tell me

What is a flow chart?

A flow chart is a diagram that shows how a complex process can be broken down into a linear sequence of events. They are useful for breaking down processes into a series of steps, when each step depends on the step before.

A concept map is also useful for showing complex ideas, but it classifies a larger topic into smaller and smaller ideas. It explains the relationships between parts or elements with statements on the links between them.

FIGURE 10.63 A flow chart showing a sequence of events

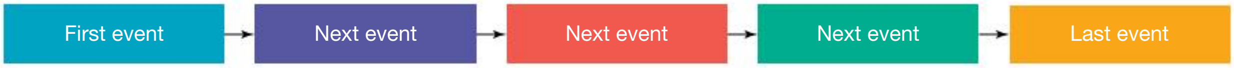
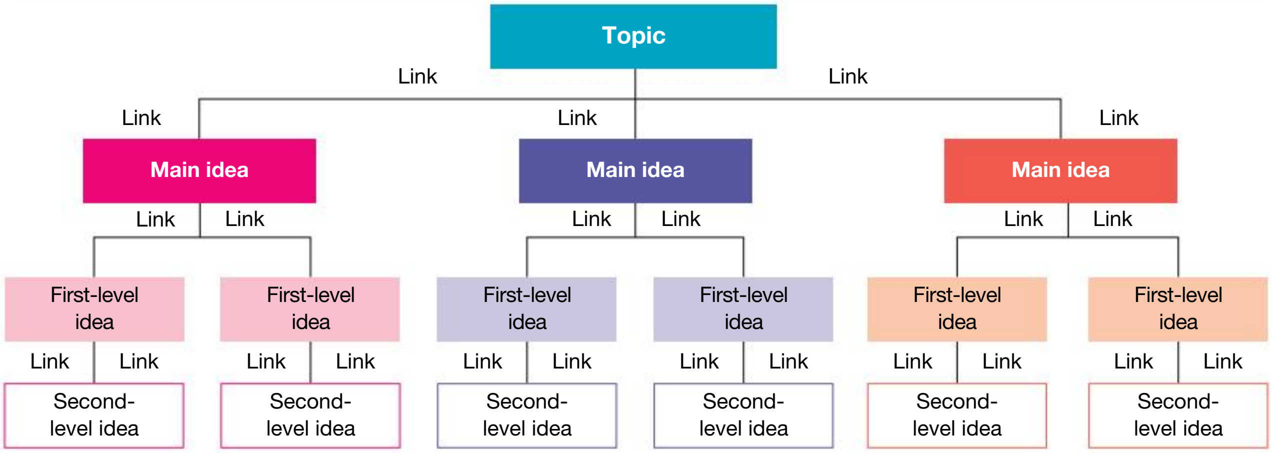


FIGURE 10.64 A concept map showing a large topic broken down into main ideas, and the relationships within each idea

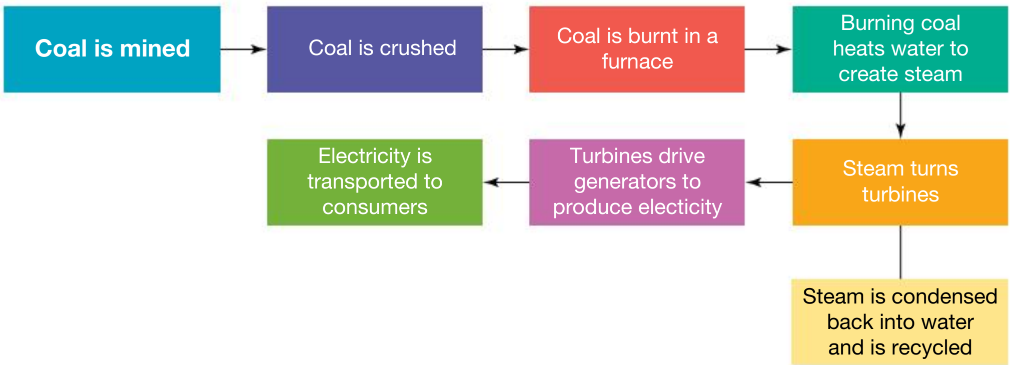


10.13.2 Show me

To create a flow chart:

1. Choose a topic or process that has a number of different parts or events. Write any ideas you may have onto small pieces of paper and arrange them from the first event through to the last. For example, you might choose to consider how electricity is produced from fossil fuels.

FIGURE 10.65 Flow chart of coal energy production

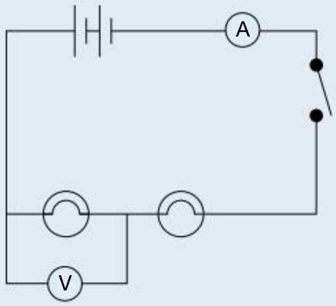


10.13.3 Let me do it

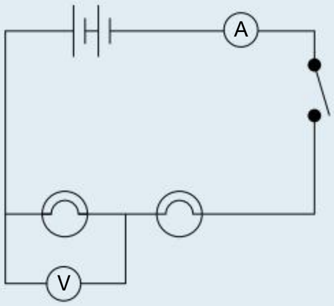
10.13 ACTIVITIES

1. Create two separate flow charts that show, step by step, how to connect each of the circuits below so that the light globes glow.

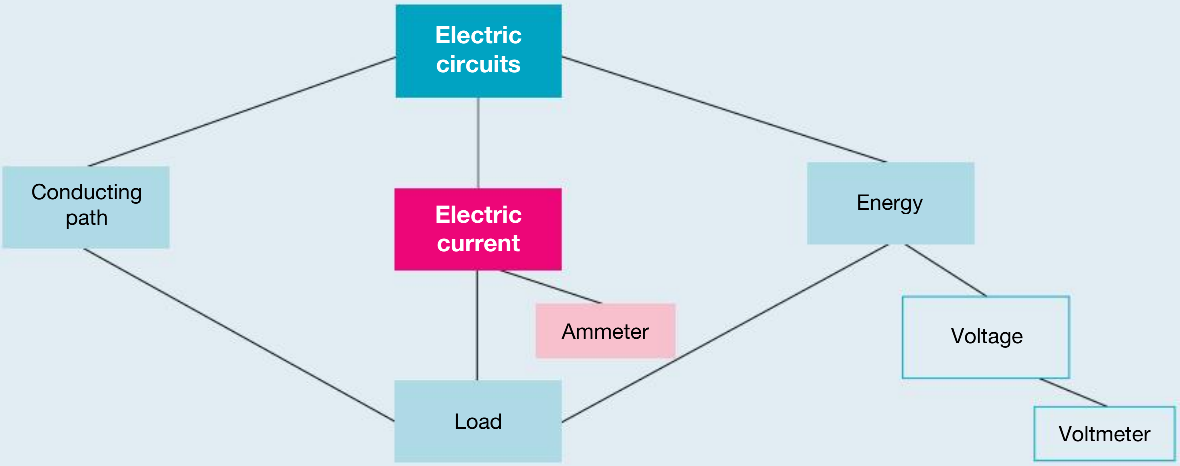
a.



b.



2. The incomplete concept map below represents some of the key ideas related to electric circuits. This concept map is just one way of representing ideas about matter and how they are linked. Copy and complete the concept map by writing suitable links between the ideas.



3. Write each of the ideas included in the concept map above and each of the terms in the box below on a small piece of paper such as a 'sticky note'. Create a concept map of your own by arranging the ideas. Write links in light pencil at first in case you want to make changes to your arrangement.

Electric circuit ideas		
resistance	circuit diagram	filament
in parallel	switch	Ohm's Law
in series	electrons	load
power supply	potential difference	power supply

4. Use sticky notes and A3 paper to create a concept map for the topic of household electricity. Use the ideas in the box below and add as many other ideas as you can.

Household electricity ideas		
alternating current	main switch	appliances
electric power	transformer	voltage
in parallel	rectifier	safety
direct current	electrical energy	circuit breaker

Fully worked solutions and sample responses are available in your digital formats.

10.14 Project — Go-Go Gadget online shop

Scenario

We use the term technology to describe the application of science to develop devices, machines and techniques to make some aspects of our lives easier. Televisions, satellites and the internet are all pretty obvious examples of technology, but small devices such as the automatic cat-flap and the humble vegetable peeler are also forms of technology. Small or specialised pieces of technology such as these are often referred to as gadgets. Every year, patents for thousands of such gadgets are issued to inventors. Some of them, like the NavMan, are immediate successes, while others — for example, a combination shoe-polisher and toothpick — don't make it into mass production. So what happens if you need a device to do a particular job but no-one has ever made one?

This is just what you and your partners were thinking when you decided to open the Go-Go Gadget online shop. Once established, clients would browse designs for gadgets that you have already developed or ask you to design something new for them that will do the job they need done. Maybe the client wants a hamster wheel that can drive a coffee-grinder or a signalling device that will tell a cat-owner whether their cat has come inside through the cat-flap or is still outside. They just tell you what they need and you design it for them! You then ship them the design, the parts they need to assemble it and an instruction brochure.

To get the business started, you decide to take out a business loan with the bank. The bank manager is intrigued with the idea but wants some assurance that you know what you are doing before they hand over the money.

Your task

As part of your presentation to the bank, you and your business partners are to develop a design for one of the following clients.

- Taylor wants a snooping-parent device that will warn her when one of her parents is coming up the hallway that leads to her bedroom. This device will give her a silent signal so she has time to turn off her computer and open her homework books before they open the door and catch her playing computer games or surfing the net instead of working.
- Heisenberg has an office on the top floor of his house. His cat, Schrödinger, can enter the house through a cat-flap in the door downstairs. When Heisenberg is locking up the house to go out or to bed, it would save a lot of time if he could know whether the cat is already inside the house. He needs a device that is connected to the cat-flap that sends a signal to Heisenberg upstairs indicating whether the cat has come in or gone out the cat-flap.
- Felicity often works until late at night and doesn't get time to exercise her dog by taking her out for a walk. She can use her computer at work to turn on switches in her apartment, and wants a device that will allow her to exercise her dog by remote control without the dog leaving the apartment.

You will then create the following to submit to the bank in support of your loan application.

1. A brief overview (approximately 300 words) of why there is a market for the services of your online shop. To support your argument, you should include references to gadgets that have been successfully developed.
2. A brochure for the gadget you have designed that includes:
   - a diagram of your design
   - a list of parts that are included in the package sent with the brochure
   - instructions on assembly or installation of the gadget
   - a troubleshooting guide to solve problems.

on Resources

ProjectsPLUS Go-Go Gadget online shop (pro-0110)

10.15 Review

Access your topic review eWorkbooks

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-4519	ewbk-4521	ewbk-4523

on Resources

10.15.1 Summary

Static electricity

- Objects can have positive or negative charge or be neutral.
- Two objects with the same charge will repel, but two objects with different charge will attract.
- Charges are surrounded by electric fields, represented by lines of force. Around a point charge these are radial and the spacing represents the strength of the field. Arrows on the lines show the direction a positive charge would feel a force in the field.
- Insulators can be charged by friction if rubbed with another insulator.
- Charged objects can attract neutral objects by inducing a charge in them.

Electrical circuits

- Electrical circuits consist of a power supply, a load and a conducting path.
- A load is an energy converter where the electrical energy carried by the electric charge is converted into useful forms of energy (for example, light, heat, sound, movement).
- Loads push back against the power supply as resistance. The greater the resistance, the less current can flow.
- The conducting path must be complete to allow electricity to flow through the circuit.
- Electric current is the rate of flow of electric charge.
- Voltage (potential difference) is the amount of electrical energy gained at the power supply or lost at the load by the electric charge as it moves through the circuit.
- Circuit diagrams are used to show all parts of a circuit and can be understood worldwide.

Battery technology

- Batteries are light and portable sources of electricity.
- Batteries are cells and if composed of two or more cells, they are connected in series.
- Electric cells consists of two electrodes and a substance through which the electric charge can flow. When the electrodes are joined by a conducting path a chemical reaction occurs, releasing electric charge and allowing the current to flow.
- Dry cells contain two electrodes: a central rod of carbon (connected to positive terminal) and zinc case (connected to negative terminal).
- Citrus fruits can be used to make a battery as a chemical reaction takes place with the acids and a small electric current will flow.
- Car batteries consist of six cells connected in series.

Series and parallel circuits

- In a series circuit all components are connected one after the other. If a part of the circuit is faulty, the connecting path is broken and no current will flow through the devices in the circuit.
- In a parallel circuit, each component is connected in a separate conducting path. If one part of the circuit is faulty, the other parts will still work. It allows more current from the power supply, effectively lowering the resistance. All components work at full power, which uses the power more quickly.
- Voltage is a measure of the amount of energy each electron in the circuit has.
- The electric current is a measure of the number of electrons passing through the circuit each second.

- Series circuit: The current is the same at all points in the circuit. Adding more globes increases the resistance so less current flow in the circuit, and the voltage of the supply must equal the voltage of the load — so with more components, the voltage is lowered.
- Parallel circuit: Adding more loops lowers the resistance of the circuit, so more current leaves the power supply, and the current splits at each branch and recombines when the wires reconnect. Voltage is the same across each loop.

Measuring electricity

- Ammeters measure electric current in amps (A).
- Voltmeters measure the voltage gain across the terminals of a power supply or voltage drop across parts of an electric circuit, measured in volts (V).
- Random errors are due to estimation when reading scales. They can be reduced by taking repeated readings and calculating an average.
- Systematic errors are due to incorrect use or limitations of equipment. They can be reduced by using equipment correctly and ensuring they are correctly calibrated.

Resisting the electrons!

- Electrical resistance is a measure of how difficult it is for electrons to flow through part of a circuit.
- The resistance to the flow of electric charge limits the electric current.
- Conductors have little resistance.
- Insulators have a large electrical resistance.
- Resistance (R) can be calculated by $R = \frac{V}{I}$, where V is the voltage drop in volts and I is the electric current in amperes.
- Ohm's Law states that the electric current in metallic conductors is proportional to the voltage drop across the conductor.
- Resistance can be controlled by using variable resistors (for example, changing the volume of a radio or dimmer switch on a light).

Electronics — Smaller and smaller

- Integrated circuits that contain thousands of tiny electronic components are etched onto thin pieces of silicon called chips.
- Electronics have gotten smaller over time as smaller and smaller circuits have been produced.
- Capacitors allow electric charge to be stored for a short time before allowing it to flow in a controlled way to other parts of the circuit.
- Diodes allow electric current to travel through them in only one direction and act as a valve for electricity. LEDs are used in the majority of our light bulbs.
- Transistors change the size or direction of electric current as a result of very small changes in the voltage across them, and are commonly used in speakers.
- A microprocessor is a silicon chip that is able to store information, process it and control other electric circuits.

Electricity and magnetism

- Faraday made the first electric generator (a dynamo) by using a magnetic field to produce an electric current.
- Magnets have a north pole and a south pole.
- Permanent magnets retain their magnetism at all times.
- Temporary magnets lose their magnetism when removed from other magnets.
- A magnetic field is the region in which a magnetic force exists.
- A moving charge creates a magnetic field.
- An electromagnet is a temporary magnet consisting of a coil of wire and an iron core. The coil of wire is called a solenoid.
- A magnetic field is produced in and around the solenoid when an electric current flows in the coil.
- Electromagnets can be turned on and off, allowing the field to be controlled.

The motor effect

- The motor effect is the force that a wire experiences when it carries a current through a magnetic field.
- An electric motor is a device that converts electrical energy into kinetic energy.
- Step by step … how a motor works:
  - An electric motor contains coils of wire surrounded by two or more magnets.
  - The coil produces a magnetic field when electric current flows through it.
  - There is a motor effect when this field interacts with the field of the magnets that surrounds the coil.
  - One side of the coil is pushed down and the other side is pushed up.
  - The coil rotates.
- The armature is the turning part of the motor on which coils of wire are wound.
- When electric current flows through the rotor coils, a magnetic field is produced.
- The field magnets are permanent magnets that do not move.
- The brushes allow current to travel through the rotor coils as they are connected to power and lightly touch the commutator as the armature turns.
- The shaft is part of the motor that is attached to the device the motor is turning, like a fan or gear wheel.
- The commutator allows the armature to keep rotating in the one direction.

Generators

- Alternating current (AC) flowing from an AC generator changes direction after every half turn.
- Direct current flows in one direction only and is produced by batteries or DC generators.
- AC is supplied by power stations as it is cheaper and easier to generate than DC.
- In a motor, electrical energy is converted into kinetic energy. A generator works like a motor in reverse. Kinetic energy is converted into electrical energy.
- Fossil-fuel stations generate power by burning fossil fuels (heat energy) to heat water to produce steam. The steam is under pressure, and drives a turbine (heat energy converted to kinetic energy). The turbine rotates coils inside huge electromagnets in a generators. The motion of the coils in the magnetic field produces a large voltage and, when connected to a load, a large electric current flows.
- Nuclear power stations and geothermal power stations also use energy to produce steam and drive turbines.
- Hydroelectric power stations use the gravitational potential energy of falling water to turn turbines (steam is not needed).
- Wave power compresses columns of air in tubes to drive small turbines.
- In your home, switches in two circuits must be closed to allow the electricity to flow: the main switch and the power point switch.
- Power points have three sockets; power plugs have two or three pins. Devices with uninsulated metal casings have three pins; two-pin devices are double insulated.
- Transformers use the changing magnetic field of one coil to induce a voltage in a second coil. By changing the ratio of the turns you can change the voltage of the electricity.
- Rectifiers are used in DC devices and use diodes to change the alternating current into direct current.
- Circuit breakers (or fuses) stop the flow of current if the flow is too large.
- Safety switches (residual current devices) are much faster than circuit breakers and fuses and switch off the power if a short circuit causes a dangerously high current.

The future of electricity

- In the future, power produced by nuclear fusion (joining atoms, not splitting them as in nuclear fission) would produce power without any pollution or risk of nuclear catastrophe.
- Electric components are as small as 5 nm in size. They will not get much smaller as they will not be able to contain the electrons of the electric current if they reduce in size much further.
- Cars that burn fossil fuels are being replaced by hybrid cars, which use rechargeable batteries and a small petrol engine, or by electric cars, which only use batteries — they do not produce pollution.

10.15.2 Key terms

alternating current current that changes direction along a wire a number of times per second
ammeter device used to measure the amount of current in a circuit. Ammeters are placed in series with other components in a circuit.
armature the turning part of an electric motor on which coils of wire are wound
brushes part of an electric motor that allows current to travel through the rotor coils by being connected to the power supply and lightly touching the commutator
cell a single battery
chemical reaction a chemical change in which one or more new chemical substances are produced
chips tiny pieces of silicon onto which tiny electric circuits can be etched
circuit breaker safety device that breaks a circuit if the current suddenly exceeds a specified size
circuit diagram diagram using symbols to show the parts of an electric circuit
commutator device attached to the rotor shaft that receives the current. In most motors it is a metal ring split into sections.
components in circuits are the individual electrical devices that are connected in the circuit by conducting wires
conducting path connected series of materials along which an electric current can flow
conductors materials that have a very low resistance, allowing current to flow through them with ease
current electricity the flow of electrons through a region
defibrillator a device that delivers a large electric shock to the heart in an attempt to reset its rhythm back to a regular pulse
diaphragm cone of a loudspeaker that vibrates to produce a sound wave
discharged excess charge is removed from an object, either by removing the charged particles, or adding an equal amount of charge of the opposite sign
dry cells devices containing chemicals as solids and pastes that react to supply an electric charge
dynamo electric generator
earthed excess charge is taken away from the object, by connecting it to the ground
earth socket connection that provides a route for current to flow to the ground when an electrical appliance malfunctions
electrical conductors materials through which electricity flows easily
electrical insulators materials which do not allow electricity to flow easily
electric charge physical property of matter that causes it to experience a force when near other electrically charged matter. Electric charge can be positive or negative.
electric current a measure of the number of electrons flowing through a circuit every second
electric generator device that transforms kinetic energy of rotation into electrical energy
electric motor device that converts electrical energy into kinetic energy of a rotating shaft
electrodes conductor through which an electric current enters or leaves a cell
electrolyte acid, base or salt that conducts electricity when dissolved in water or melted
electromagnet magnet formed by wrapping a coil of wire around an iron core. When electricity passes through the coil, the iron core becomes an electromagnet.
fibrillation rapid twitching of the heart muscle, which disrupts its rhythm; can cause heart attacks
field magnets magnets producing a magnetic field that acts on the rotor coils
filament coil of wire made from a metal that glows brightly when it gets hot
fuse safety wire that melts when too much current flows through it. Fuse wires are designed to melt at different currents.
induction a process where the electrical or magnetic properties of an object produces similar properties in a nearby object without physical contact; for example, the production of a current by repeatedly moving a magnet in and out of a coil
insulators materials that have a very high resistance, allowing very little current to flow through them
integrated circuits electric circuits made up of miniature components that can be etched onto silicon chips
light-emitting diodes a device that emits visible light when a current, which flows in one direction only, passes through it
load device that uses electrical energy and converts it into other forms of energy
magnetic field area where a magnetic force is experienced by another magnet. The direction of the magnetic force is shown by drawing field lines; the size of the force is shown by how close together the lines are.
main switch control switch that turns all the household circuits on or off
microprocessor electronic central processing units of computers on a microchip

negatively charged having more electrons than protons (more negative charges than positive charges)
north pole end of the magnet that when free to rotate, points to the north pole of the Earth
ohmic describes conductors that obey Ohm's Law
Ohm's Law states that the current in a conductor is proportional to the voltage drop across the conductor
parallax error error caused by reading a scale at an angle rather than placing it directly in front of the eye
parallel circuit a circuit that has more than one path for electricity to flow through. If one of the paths has a break in it, the others will still work.
permanent magnets magnets that retain their magnetic effect for many years
positively charged having more protons than electrons (more positive charges than negative charges)
potential difference also known as voltage, is the change in the amount of energy stored in electrons as they move through a component or a circuit
power supply a device that can provide an electric current
random errors an error that occurs due to estimation when reading scales, or when the quantity being measured changes randomly
rectifier device that changes alternating current to direct current
residual current devices a form of safety switch that can quickly detect a possible fault and break the flow of electricity in a circuit in order to prevent electrocution
resistance measure of the electrical energy required for an electric current to pass through an object, measured in ohms (Ω)
resistors circuit component that has resistance
rotor coils coils of a motor that turn when a current flows through them
series a formation of electricity-generating or using devices whereby the electricity passes from one device to the next in a single conducting loop, one after the other
series circuit a circuit with the components joined one after the other in a single continuous loop
shaft central rotating rod of the motor that transmits the kinetic energy
solenoid coil of wire able to pass a current
south pole end of a magnet opposite the north pole
static electricity a build-up of charge in one place
switch device that opens and closes the conducting path through which a current flows
systematic errors errors that are consistently high or low due to the incorrect use or limitations of equipment
temporary magnets magnets that stay magnetic while in contact with a permanent magnet, or one that is magnetic for a very short time
transducer a device that converts energy from one form into another form
transformer device that can increase or decrease voltages for alternating current
variable resistor device for which the resistance can be altered
voice coil coil of wire in a loudspeaker that vibrates at the frequency of the electrical signal. This frequency matches the frequency of the sound produced by the cone.
voltage the amount of energy that is pushing electrons around a circuit, per coulomb of charge that flows between two points
voltmeter device used to measure the voltage across a component in a circuit. Voltmeters are placed in parallel with the components.

on Resources

eWorkbooks	Study checklist (ewbk-4525) Literacy builder (ewbk-4526) Crossword (ewbk-4528) Word search (ewbk-4530)
Practical investigation eLogbook	Topic 10 Practical investiation eLogbook (elog-4503)
Digital document	Key terms glossary (doc-34887)

10.15 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 5, 7, 9, 10	Questions 3, 4, 8, 11, 14, 18	Questions 6, 12, 13, 15, 16, 17, 19

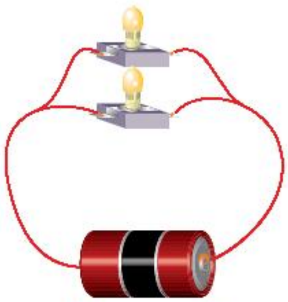
Remember and understand

1. Match each term with its correct description.

Term	Description
Static electricity	A material that allows current or heat to flow through it
Electron	Positively charged particle in the nucleus of an atom
Proton	The build-up of charge on an object
Current	A material that does not allow current or heat to flow through it easily
Voltage	Particle in an atom with a negative charge
Conductor	A path that has no breaks in it
Closed circuit	The energy supplied to move electrons around a closed circuit
Insulator	The flow of electrons around a closed circuit

2. Identify each of the following circuits as a parallel circuit or series circuit.

a.



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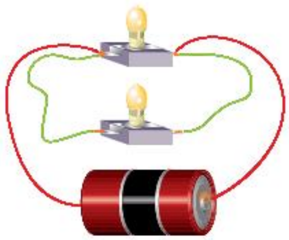
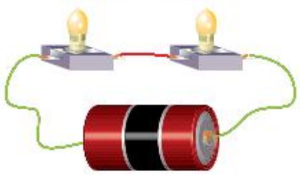
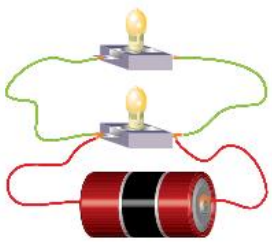


c.



d.



3. MC In which one or more of the following arrangements will the globe light up?

A.

B.

C.

D.

4. MC Which physical quantity is a measure of a change in energy?

A. Voltage B. Current C. Resistance D. Power

5. Complete the table by writing down the missing quantity, unit or abbreviation.

TABLE Electrical quantities

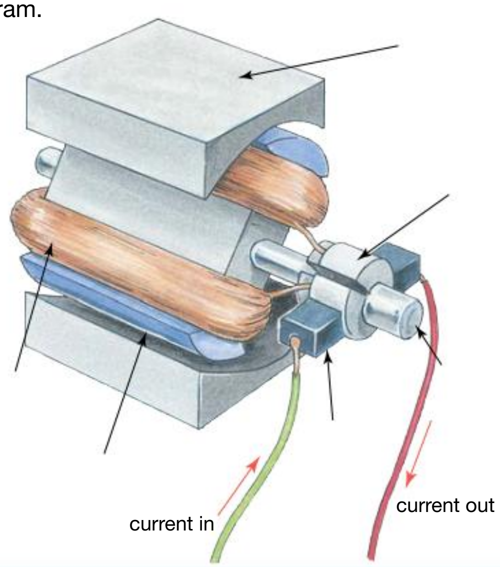
Quantity	Unit	Abbreviation
Voltage	volt	
Electric current		A
	ohm	

6. List three changes that can be made to an electric generator to increase the size of the electric current it produces.

Apply and analyse

7. Use symbols to draw a circuit containing a light globe in series with an ammeter, a battery and a switch.
8. Draw a circuit diagram that shows how a voltmeter and ammeter are used to measure the voltage across and current flowing through a single light globe connected to a 6-volt power supply. Label the positive and negative terminals of the power supply and each meter with + and – symbols.
9. What is the electric current being shown on the ammeter if the positive lead is placed in the:
   a. 500 mA terminal
   b. 5 A terminal?

10. How does increasing the resistance of a variable resistor in series with a power supply and a lamp affect the:
    a. electric current in the lamp
    b. voltage across the variable resistor
    c. voltage across the lamp?
11. Compile a list of all devices that you would expect to contain microprocessors. For each item, briefly state why you believe it contains microprocessors.
12. Consider the diagram of the DC electric motor.
    a. Complete the labelling of the diagram.

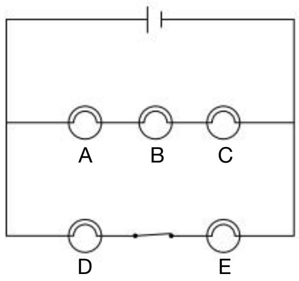


b. Complete the table to indicate the role of each of the parts of the motor listed.

TABLE Motor parts and purpose

Part	Purpose
field magnets	
armature	
rotor coil	
shaft	
brushes	
commutator	

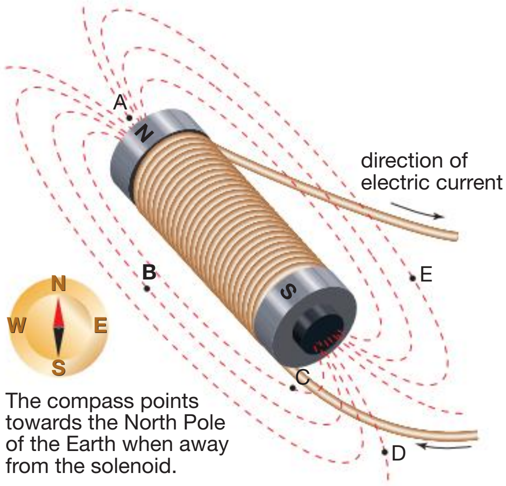
Questions 13 and 14 refer to the circuit diagram shown. The light globes, labelled A to E, are identical to each other.



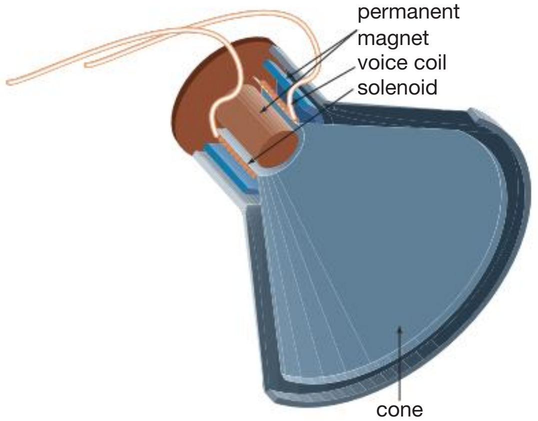
13. a. Which of the light globes are connected:
    i. in series with globe A
    ii. in parallel with globe A?
  b. If the voltage across globe C was measured to be 4 volts, what is the voltage across:
    i. globe A
    ii. the terminals of the power supply
    iii. globe E?
  c. If the electric current flowing through globe B was measured to be 200 mA and the electric current flowing through globe D was measured to be 300 mA, what is the electric current flowing through:
    i. globe A
    ii. globe E
    iii. the power supply?
14. a. If the filament in globe B was to break, which of the light globes would remain glowing?
  b. If the switch in the circuit was opened, which light globes would stop glowing?
  c. How could you make all of the light globes stop glowing without opening the switch or turning off the power supply?
  d. The voltage across globe C is measured to be 4 volts and the current flowing through it is 200 mA.
    i. What is the electric current flowing through globe C, in amperes?
    ii. What is the resistance (in ohms) of globe C while this current is flowing?
15. Many electrical devices contain electromagnets.
  a. Is an electromagnet a permanent or temporary magnet? Explain your answer.
  b. Which part of an electromagnet is the solenoid?
  c. What is the role of the iron core in an electromagnet?
16. Imagine that you were given a 3-metre length of wire, an A4 sheet of thin card and a bar magnet.
  a. Explain how you could produce an electric current.
  b. What piece of equipment would you need to demonstrate that an electric current was produced?

Evaluate and create

17. SIS In what way does a conductor that obeys Ohm's Law behave differently from one that doesn't? Sketch a graph to support your answer.
18. Consider the figure.
    a. Draw arrows at each of the points A, B, C, D and E to show the direction that the compass needle would point if the compass was placed at each of the points when an electric current flows in the solenoid as shown.
    b. At which of the points A, B, C, D or E is the magnetic field the strongest?



19. SIS Create a flow chart to show how a moving coil speaker transforms electrical energy into the sound energy that you hear.



Fully worked solutions and sample responses are available in your digital formats.

on Resources

eWorkbook Reflection (ewbk-3038)

teachon

Test maker
Create customised assessments from our extensive range of questions, including teacher-quarantined questions. Access the assignments section in learnON to begin creating and assigning assessments to students.

RESOURCE SUMMARY

on Resources

Below is a full list of **rich resources** available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

10.1 Overview

eWorkbooks
- Topic 10 eWorkbook (ewbk-4501)
- Student learning matrix (ewbk-4500)
- Starter activity (ewbk-4503)

Practical investigation eLogbook
- Topic 10 Practical investigation eLogbook (elog-0468)

Video eLesson
- Building electronic circuit boards (eles-4152)

10.2 Static electricity

Practical investigation eLogbook
- Investigation 10.1: Producing different charges (elog-0444)

Video eLesson
- Van de Graff generator (eles-2671)

10.3 Electrical circuits

eWorkbooks
- Conductors and insulators (ewbk-4505)
- Simple circuits (ewbk-4507)

Practical investigation eLogbooks
- Investigation 10.2: Making the right connections (elog-0446)
- Investigation 10.3: What's inside a torch? (elog-0448)

10.4 Battery technology

eWorkbook
- Testing batteries (ewbk-4509)

Practical investigation eLogbook
- Investigation 10.4: A lemon battery (elog-0450)

Video eLessons
- Volta's pile and the age of steam (eles-1777)
- Fruity cells (eles-2673)

10.5 Series and parallel circuits

eWorkbook
- Series and parallel circuits (ewbk-4511)

Practical investigation eLogbooks
- Investigation 10.5: Series and parallel circuits (elog-0452)
- Investigation 10.6: Switched-on circuits (elog-0454)

Video eLessons
- The hydraulic model of current (eles-0029)
- Parallel circuits (eles-2672)

Interactivity
- Voltage rises and fall in a simple circuit (int-5776)

10.6 Measuring electricity

eWorkbook
- Ammeters and voltmeters (ewbk-4513)

Practical investigation eLogbook
- Investigation 10.7: Probing a simple circuit (elog-0456)

10.7 Resisting the electrons!

eWorkbook
- Ohm's Law (ewkb-4515)

Practical investigation eLogbooks
- Investigation 10.8: Changing resistance (elog-0458)
- Investigation 10.9: Making the change (elog-0460)

Video eLesson
- Four different resistors (eles-2674)

10.8 Electronics — Smaller and smaller

Interactivity
- Electronic building blocks (int-5781)

10.9 Electricity and magnetism

eWorkBook
- Exploring magnets and magnetic fields (ewbk-4517)

Practical investigation eLogbooks
- Investigation 10.10: Mapping the magnetic field (elog-0462)
- Investigation 10.11: A look at the field (elog-0464)

10.10 The motor effect

Video eLesson
- Vibration of a speaker diaphragm (eles-2675)

10.11 Generators

Practical investigation eLogbook
- Investigation 10.12: Electrical energy from kinetic energy (elog-0466)

Interactivities
- Magnetic flux and Lenz's law (int-0050)
- Circuit breakers (int-5777)

10.12 The future of electricity

Video eLesson
- The Australian-International Model Solar Challenge (eles-0068)

10.14 Project — Go-Go Gadget online shop

ProjectsPLUS
- Go-Go Gadget online shop (pro-0110)

10.15 Review

eWorkbooks
- Topic review Level 1 (ewbk-4519)
- Topic review Level 2 (ewbk-4521)
- Topic review Level 3 (ewbk-4523)
- Study checklist (ewbk-4525)
- Literacy builder (ewbk-4526)
- Crossword (ewbk-4528)
- Word search (ewbk-4530)
- Reflection (ewbk-3038)

Practical investigation eLogbook
- Topic 10 Practical investigation eLogbook (elog-0468)

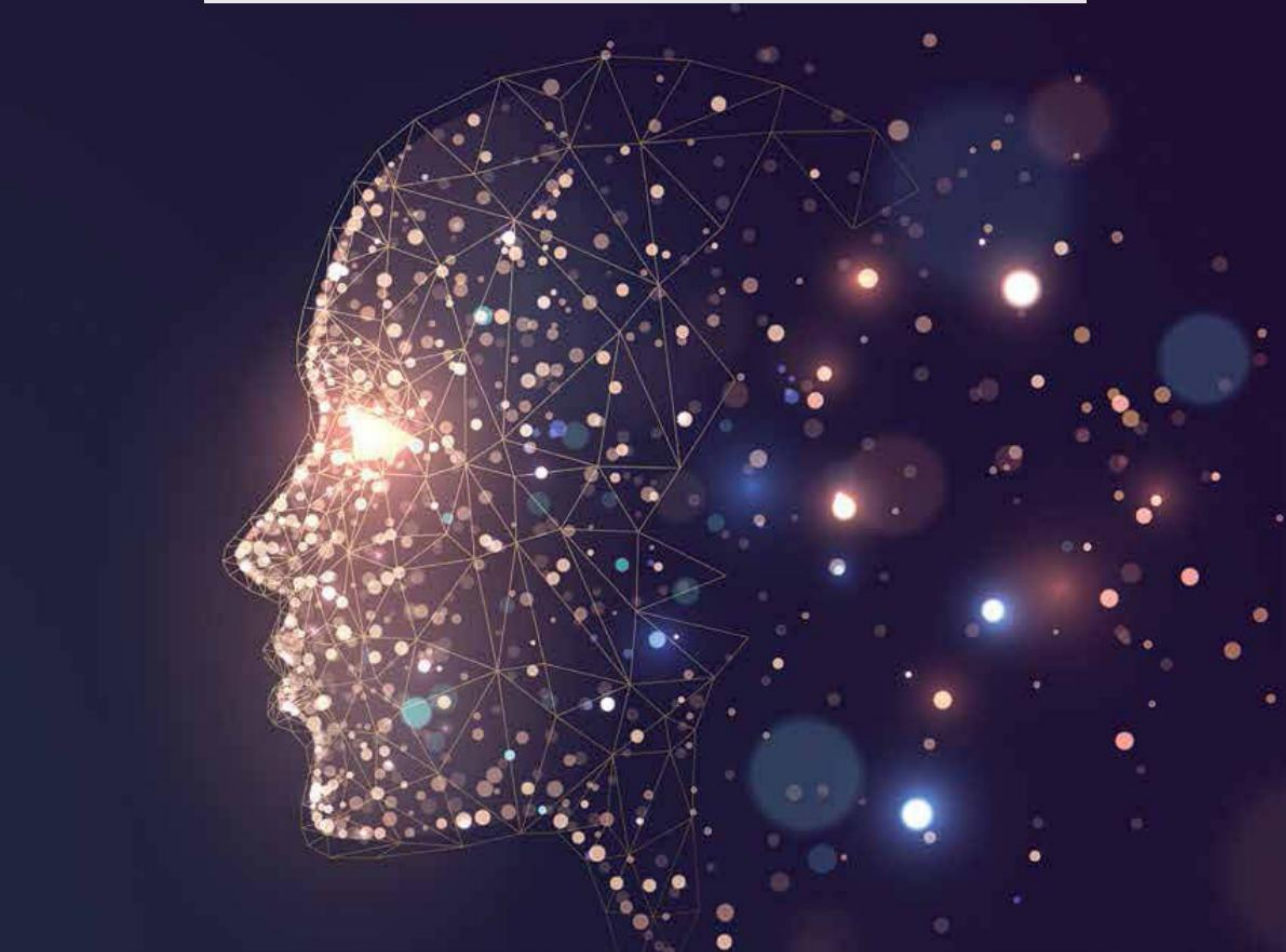
Digital document
- Key terms glossary (doc-34887)

To access these online resources, log on to **www.jacplus.com.au**.

11 Psychology

LEARNING SEQUENCE

11.1 Overview
11.2 Introducing psychology
11.3 The brain
11.4 Intelligence
11.5 Emotions and communication
11.6 Sleep and sleep disorders
11.7 Psychopathology
11.8 Treatment of mental disorders
11.9 Groups and social psychology
11.10 Forensic psychology
11.11 Review



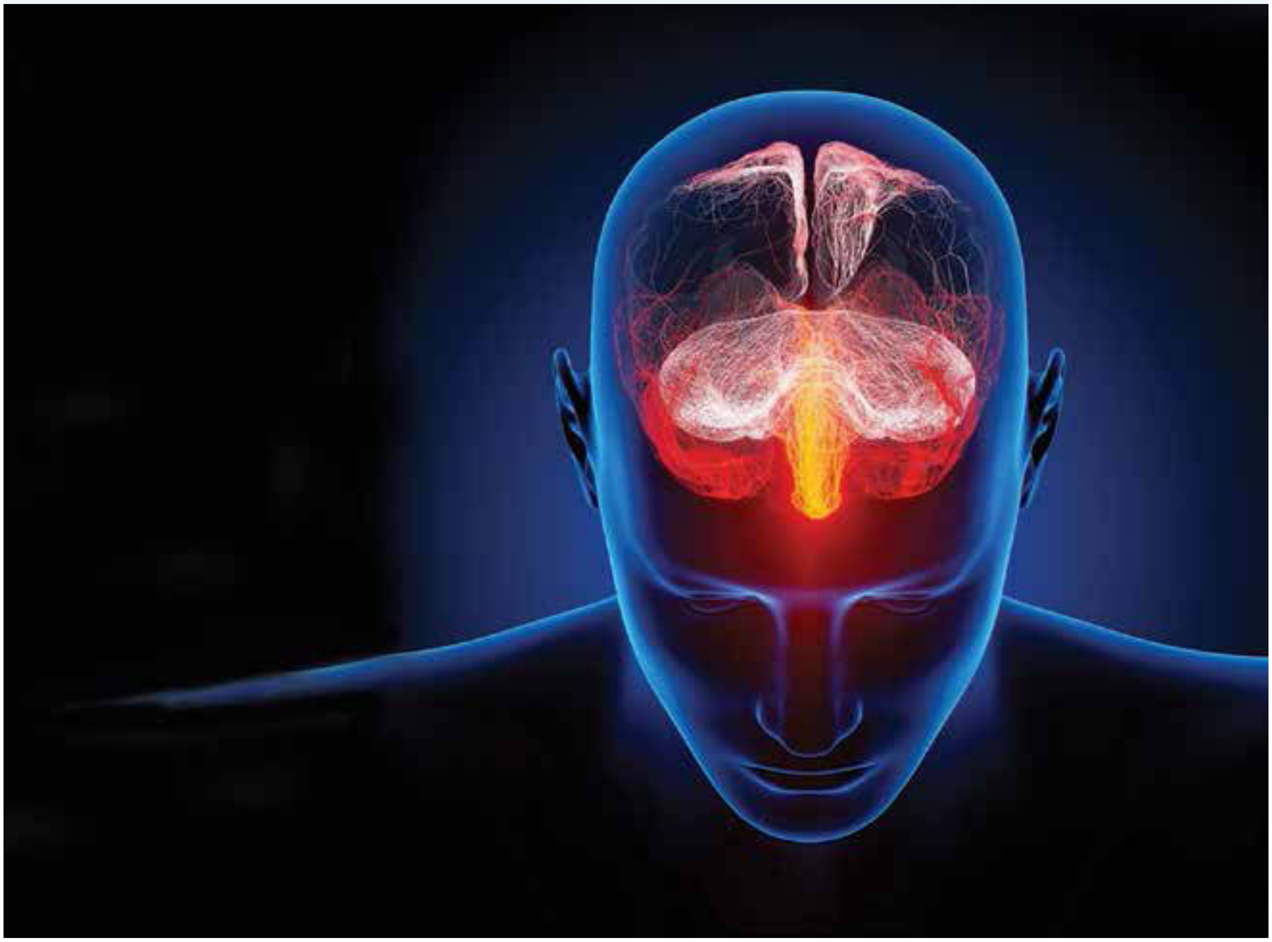
11.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

11.1.1 Introduction

Humans need to react to changes both within and outside their bodies. The brain is the control centre of the human body. It allows us to sense and perceive, interpret and react to our environment — every second of every day. Our brain controls how we think, feel and behave. Without it we would be unable to solve a difficult maths problem, remember our last birthday or sing our favourite song. The branch of science that investigates how our brain influences our thoughts, feelings and behaviours is called psychology. Psychology is a growing science, investigating interesting ideas such as why serial killers kill, why we compete against each other and why stress makes us sick.

FIGURE 11.1 Psychology is the study of the brain — thoughts, feelings and behaviours.



11.1.2 Think about psychology

1. Without our brain, what would we be able to do? What wouldn't we be able to do?
2. What areas of psychology have you already heard about?
3. Name as many movies or television shows as you can that have depicted someone with a mental disorder.
4. How does the brain control our behaviour?

11.1.3 Science inquiry

Designing experiments in psychology

Like other branches of science, psychology relies on the scientific method for design of experiments. Using the scientific method allows researchers to conduct studies in a consistent, structured manner that allows them to draw appropriate conclusions from the data collected. However, as psychology is the study of human thoughts, feelings and behaviours, the experiments in psychology often rely on human volunteers.

The participants in a research study are referred to as a **sample**. A sample is a group of individuals selected from a larger group that has been chosen to be studied (known as a **population**). A sample is a critical element in psychological research. It should be representative of the population of interest and of sufficient size to ensure that accurate conclusions and generalisations are able to be drawn from the research.

Experimental groups and control groups

In an experiment, participants allocated to the **experimental group** are exposed to the *variable* being tested — known as the *independent variable*. The experimental group is often also referred to as the *treatment group*.

Participants allocated to the **control group** *are not* exposed to the variable being tested (the independent variable). However, they are treated exactly the same way as the experimental group in all other aspects of the experiment. These participants are used as a means of *comparison* with the experimental group.

sample a smaller group of individuals selected from a larger group that has been chosen to be studied

population the entire group of people who are being studied from which a sample is selected

experimental group a group of participants within an experiment who are exposed to the variable being tested

control group a group of participants within an experiment who are not exposed to the variable being tested, and are used to compare to the experimental group

Experiment to test influence of energy drink on performance at the gym

Researchers wanted to test the effects of a new energy drink, *Fast Emu*, on people's energy levels at a gym. Researchers hypothesised that people who drank *Fast Emu* before their fitness session would perform better throughout the session compared to those people who drank water only.

1. Identify the independent variable and the dependant variable for this research topic.
   To minimise participant-related variables (individual differences between people), researchers chose to use a matched-participants design for this experiment, where individuals are 'matched' on personal characteristics, skills or abilities that relate to the research.
2. Suggest a sample group for the experiment. Remember the sample group should be representative of the population of interest and of sufficient size to ensure that accurate conclusions and generalisations are able to be drawn from the research.
3. Suggest a research hypothesis.
4. Suggest an experiment to test the hypothesis, identifying the method for the control group and the experimental group.

on Resources

eWorkbooks Psychology eWorkbook (ewbk-6424)
Student learning matrix (ewbk-6426)
Starter activity (ewbk-6427)

learnon Access and answer an online Pre-test and receive **immediate corrective feedback** and **fully worked solutions** for all questions.

11.2 Introducing psychology

LEARNING INTENTION

At the end of this subtopic you will be able to recognise that psychology is the study of the mind, through thoughts, feelings and behaviours, and be able to provide examples of some different types of psychologists.

11.2.1 Psychology is a science

The term **psychology** originated from two Greek terms — *psyche*, which means mind, and *logos*, which means study or knowledge. Therefore, psychology can be explained as the study of the mind. This definition has broadened over time, and the most currently accepted definition of psychology is *the systematic study of thoughts, feelings and behaviours*.

FIGURE 11.2 Differentiating between thoughts, feelings and behaviours

Thoughts	Feelings	Behaviours
A thought (mental activity or cognition) is like a person inside your head talking to you. A dog walking down the street may make you think 'That dog looks sad. I wonder if he is lost.'	A feeling is the emotion that you have at any one time. Examples of feelings include sadness, anger, and happiness. Another name for feelings is affect.	A behaviour is any observable action. This means anything you do. An example of a behaviour is jumping up and down or patting a dog.

Psychology is a science. This means that everything we know about the mind, thoughts, feelings and behaviours comes from research. Research in psychology is conducted in a systematic and planned way, known as **scientific method**. Information is collected either by directly observing a person or animal's behaviour, or by conducting an experiment. This is similar to other sciences, such as biology or chemistry.

There are also many other ways of explaining human behaviour that are not based on science. Some of these approaches claim to be scientific, but are not. Some have scientific sounding names such as astrology, numerology and palmistry. These types of non-sciences are often referred to as **pseudosciences** (*pseudo* meaning fake).

psychology the systematic studies of thoughts, feelings and behaviours

scientific method a systematic and logical process of investigation to test hypotheses and answer questions based on data or observations

pseudosciences fields that are not sciences, despite having scientific sounding names or claiming to be scientific

11.2.2 Working as a psychologist

There are many areas in which **psychologists** can work; however, most psychologists specialise in one or two specific areas. These specialty areas include sport, forensic, health, counselling, clinical, neuropsychology, academic, educational and organisational psychology.

Sport psychologists

int-7051

- Help professional athletes develop psychological skills to positively influence their athletic performance and physical activity (for example, goal setting, confidence, imagery)
- Help athletes psychologically deal with the demands of competitive sport and increase motivation
- Aassist athletes to recover from injuries and to continue practising in off-peak periods

FIGURE 11.3 Sport psychologists support athletes during training and recovery.

Forensic psychologists

- Psychological assessment of criminals
- Determining diminished responsibility and insanity
- Counselling victims and eye witnesses
- **Criminal profiling**
- Researching jury behaviour
- Researching memory; for example, understanding how reliable a witness' account may be in court
- Understanding jury behaviour including potential bias by outside information or their own perceptions

Clinical psychologists

- Assessment, diagnosis and treatment of severe and non-severe mental disorders and psychological problems
- Integrate science, theory, and clinical knowledge in understanding, preventing, and relieving psychologically-based distress or dysfunction
- Promote wellbeing and personal development

Counselling psychologists

- Counselling less severe forms of psychological distress such as relationship issues, self-esteem struggles, conflicts, problems with substance abuse, career issues
- Evaluate their patients' situations, problems and issues and offer advice or coping strategies

psychologists an expert or specialist in psychology

criminal profiling a profile detailing the physical and behavioural traits of a criminal that is used by detectives and police

Neuropsychologists

- Researching how the brain and nervous system influence a person's cognition and behaviours
- Study how injuries or illnesses to the brain affect cognitive functions and behaviours.
- Rehabilitation of brain injuries (due to traffic accidents and strokes)
- Illness rehabilitation and research (due to epilepsy and dementia)

FIGURE 11.4 Neuropsychologist studying MRI (magnetic resonance imaging) scans of teenagers' brains

Organisational psychologists

- Work within industries and companies to recruit and select the most appropriate people for a position using psychological testing and behavioural interviewing

- Develop learning and training tools for individuals, teams or the entire organisation
- Coaching, mentoring and career development to improve and manage workplace performance
- Assisting in team building, effective management and leadership strategies in the workplace
- Improving productivity and morale

Health psychologists

- Research and health promotion
- Work with community members and professionals by developing educational and behavioural programs that positively influence health and wellbeing
- Estimate the distribution of disease and design public health programs
- Implement public health programs and counselling that lead people to make behavioural changes (eating disorders, exercise, substance abuse, addiction, gambling, injury/cancer prevention such as 'SunSmart')

Academic psychologists

- Working in universities lecturing, doing research and supervising students doing research

Educational psychologists

- Assisting in learning and developmental issues such as sibling rivalry, bullying, peer pressure, parenting and psychological assessment of learning disabilities
- Work closely with students (and their parents) by investigating how they learn and process information; they help children with any developmental issues or learning disabilities that are hindering their progress
- Finding ways to improve student learning outcomes and examine how emotional issues, one's attitudes, motivation, self-regulation, behaviour and self-esteem contribute to learning.

The difference between a psychologist and a psychiatrist

People who have studied psychology at university and have become experts in the study of thoughts, feelings and behaviours are called psychologists. **Psychiatrists** are also experts in these fields, but they are qualified medical doctors who can perform medical procedures and prescribe medicine to treat mental illnesses as well.

psychiatrists medical doctors that specialise in the diagnosis and treatment of medical illness

DISCUSSION

Think about the issues facing young people today that might require a psychologist. Classify these issues as to what type of psychologist would be the most appropriate to speak to.

on Resources

assesson Additional automatically marked question sets

11.2 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2	Questions 3, 4	Question 5

Remember and understand

1. What is *psychology*?
2. a. What are the differences between a psychologist and a psychiatrist?
   b. State if the following roles are carried out by a psychologist or a psychiatrist?

TABLE Roles of a psychologist or psychiatrist

Role	Psychologist or Psychiatrist
Does not prescribe medications	
Specialises in abnormal behaviour	
Completes a medical degree	
Uses treatments such as counselling and therapy	
Uses treatments such as medications	

3. Name three different types of pseudoscience.

Apply and analyse

4. Look at each of the different types of psychologists. Match the following places of employment to a type of psychologist.

Type of psychologist	Places of employment
a. Organisational psychologist	A. University
b. Educational psychologist	B. Human resources, business enterprise, private practice
c. Sports psychologist	C. Clinic, hospital, health organisation such as Anticancer Council or Eating Disorders Foundation, drug rehab centres, gambling counselling centres
d. Neuropsychologist	D. Sport team, institute of sport, club
e. Academic psychologist	E. School, university, TAFE, clinic
f. Health psychologist	F. Hospital, TAC, accident rehabilitation clinic

Evaluate and create

5. Evaluate whether each example is a thought, feeling or behaviour:

TABLE Examples of thoughts, feelings or behaviours

Example	Thought, feeling or behaviour
a. being excited about going on holiday	
b. remembering your last birthday	
c. singing along to the radio	
d. being angry at your brother	
e. trying to work out a maths problem in your head	
f. sneezing	
g. dreaming	
h. getting confused because you can't work out a maths problem in your head.	

Fully worked solutions and sample responses are available in your digital formats.

11.3 The brain

LEARNING INTENTION

At the end of this subtopic you will be able to explain the human nervous system and how the hemispheres of brain work together by sharing information through the corpus callosum.

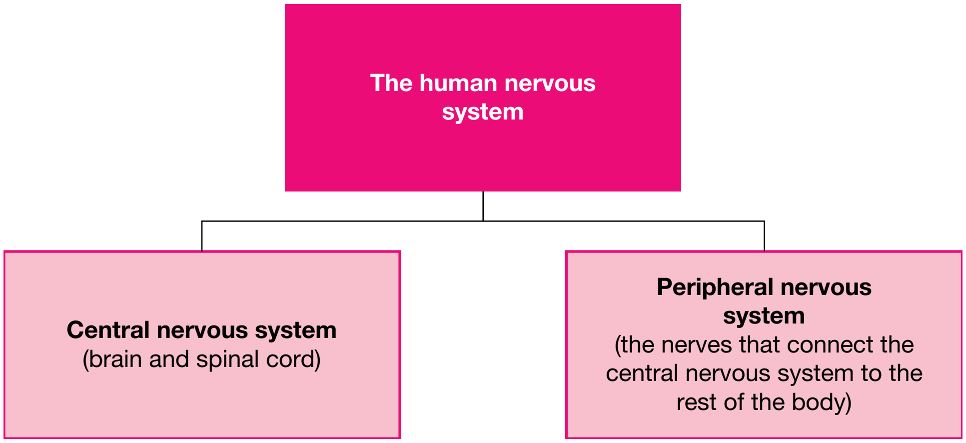
11.3.1 Nervous systems

All living animals have nervous systems. At the most basic level, simple animals, such as jellyfish, have very simple nervous systems containing only a few nerve cells. They have evolved to perform activities that lead to their survival ensuring the species is able to eat, breathe, move and reproduce.

Human beings need a more advanced nervous system to be able to perform complex activities such as problem solving, creative thinking, talking, playing football, engaging in relationships, or writing computer programs.

FIGURE 11.5 Jellyfish have the simplest nervous system.

FIGURE 11.6 Humans have an advanced nervous system.



The central nervous system: The brain

The brain is soft and has the appearance of an oversized, wrinkled walnut. The average brain is the size of a large grapefruit and weighs around 1.5 kilograms. The brain has many functions including controlling movement, thinking, memory and regulating the body's internal state.

The outer layer of the brain, the **cerebral cortex**, is a very important part of the brain. The cerebral cortex is bigger in humans, compared to all other animals. The roles of this part of the brain include problem solving, memory, **personality**, judging, planning, learning, logical reasoning and decision making.

cerebral cortex the outer layer of the brain, which processes information and is linked to memory and problem solving

personality the combination of characteristics or qualities that form an individual's distinctive character

The cerebral cortex is divided into two halves called **cerebral hemispheres**. The left cerebral hemisphere is mainly responsible for the functioning of the right side of the body and the right cerebral hemisphere is mainly responsible for the functioning of the left side of the body.

Each hemisphere also has other specialised functions, as are listed below. However, it is important to recognise that despite these types of specialisation, the two hemispheres share information using the **corpus callosum** and function interactively.

cerebral hemispheres the two halves of the cerebral cortex, both responsible for different ways of thinking

corpus callosum the part of the brain that connects the two hemispheres, allowing them to function interactively

ewbk-6429

int-8133

FIGURE 11.7 Parts of the brain. Note the corpus callosum is a bridge of nerve fibres that connects the left and right hemispheres of the brain.

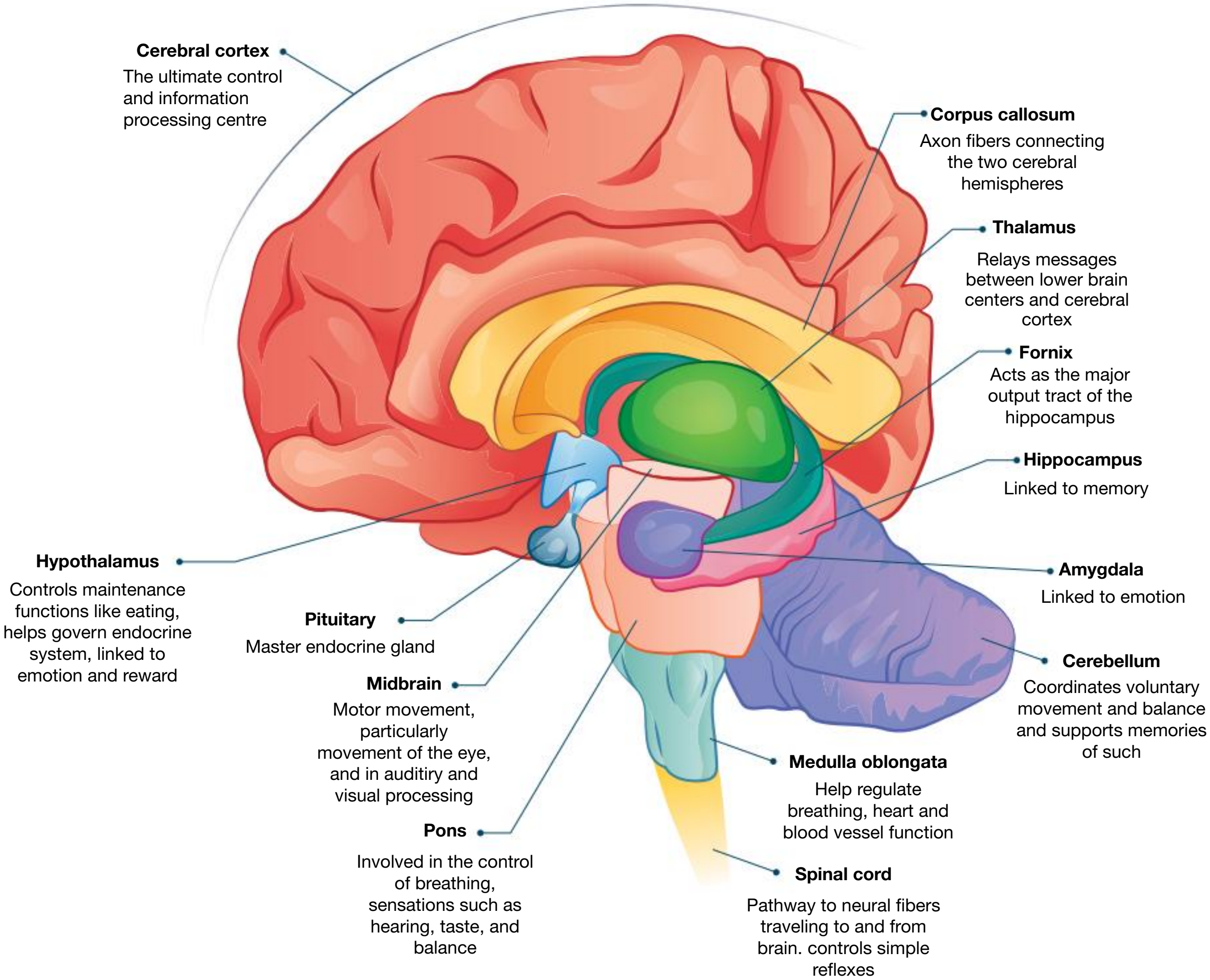


FIGURE 11.8 The left and right brain have different specialisations but work together.

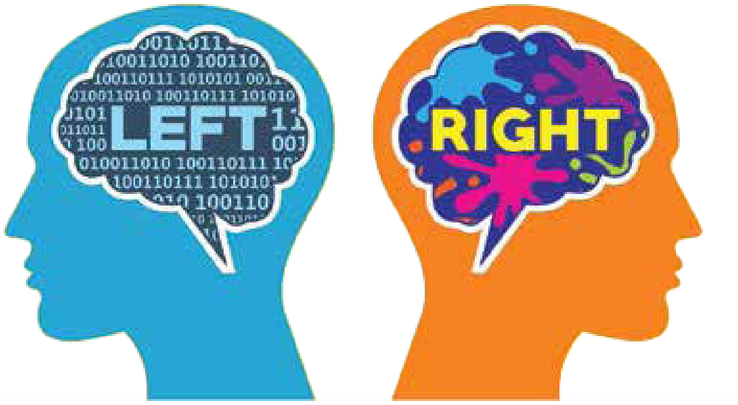


TABLE 11.1 Specialisations of the left and right hemisphere of the human brain

Left hemisphere	Right hemisphere
• Control of the right side of the body • Production and comprehension of • Language • Mathematical skills • Logical thinking and problem solving • Reasoning	• Control of the left side of the body • Non-verbal tasks • Visual/spatial tasks; for example, jigsaw • Puzzles and reading maps • Creativity • Music • Appreciation of beauty • Fantasy and dreams

ACTIVITY: What are your strengths and weaknesses at school?

Do you think that you have:

- dominant left brain
- dominant right brain
- balanced brain?

Take this questionnaire to find out.

Choose the one sentence that is more true (A or B) for each question. Do not leave any blanks, and tick only ONE answer per question.

1	**(A)**	It is fun to take risks.	☐
	(B)	I have fun without taking risks.	☐
2	**(A)**	I look for new ways to do old jobs.	☐
	(B)	When one way works well, I don’t change it.	☐
3	**(A)**	I begin many things that I never finish.	☐
	(B)	I finish something before I start something new.	☐
4	**(A)**	I’m not very imaginative in my work.	☐
	(B)	I use my imagination in everything I do.	☐
5	**(A)**	I can analyse what is going to happen next.	☐
	(B)	I can sense what is going to happen next.	☐
6	**(A)**	I try to find the best way to do something.	☐
	(B)	I try to find different answers to problems.	☐

7	**(A)**	My thinking is like pictures going through my head.	☐
	(B)	My thinking is like words going through my head.	☐
8	**(A)**	I agree with new ideas before other people do.	☐
	(B)	I question new ideas more than other people do.	☐
9	**(A)**	Other people don't understand how I organise things.	☐
	(B)	Other people think I organise well.	☐
10	**(A)**	I plan time for doing my work.	☐
	(B)	I don't think about the time when I do work.	☐
11	**(A)**	When I am making a hard decision, I choose what I know is right.	☐
	(B)	When I am making a hard decision, I choose what I feel is right.	☐
12	**(A)**	I do easy things first, and leave important things until later.	☐
	(B)	I do the important things first, and leave the easy things until later.	☐

To score:

- Give yourself one point for each time you answered A for questions: 1, 2, 9, 12.
- Give yourself one point for each time you answered B for questions: 4, 5, 10, 11.
- Add all points up. (*Note:* Some questions score 0 for middle/equal brain.)

What does this score mean?

If you scored:

0–1	Strong left brain
2–3	Moderate left brain
4–5	Middle/equal brains
6–7	Moderate right brain
8	Strong right brain

on Resources

eWorkbooks What are your strengths and weaknesses at school? (ewbk-6433)
Investigating neurons (ewbk-6431)

assess on Additional automatically marked question sets

11.3 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Describe the structure of the human brain.
2. Identify whether the following are the role of the left or right hemisphere of the brain.

TABLE Activities of left or right hemisphere of the brain

Activity	Left or right hemisphere of the brain
Creativity	
Control of the left side of the body	
Reasoning	
Visual-spatial tasks	
Control of the right side of the body	
Language	

3. Describe two main functions of the nervous system.
4. MC What is the role of the corpus callosum?
   A. Sends sensory information to the brain
   B. Connects the brain to the spinal cord
   C. Connects the left and right hemispheres
   D. Sends motor information from the brain to the rest of the body

Apply and analyse

3. What are the main differences between the left and right hemispheres of the brain?
4. Tom was in a car accident. He hit his head, and now he has trouble speaking; however, he has no problems doing jigsaws or reading maps. What part of the brain might Tom have damaged?

Evaluate and create

7. Using the following, construct a target map on brain dominance. Place the roles of the left hemisphere in the inner ring and the roles of the right hemisphere in the outer ring.
   - Writing the music for song lyrics
   - Balancing incoming and outgoing money from your bank account
   - Painting your fingernails with nail polish
   - Working out how much change you will get when shopping
   - Dancing to music
   - Reading a magazine
   - Discussing your problems with your best friend
   - Singing your favourite song

Fully worked solutions and sample responses are available in your digital formats.

11.4 Intelligence

LEARNING INTENTION

At the end of this subtopic you will be able to recognise that intelligence cannot be directly measured and be able to describe multiple intelligences proposed by a psychologist named Howard Gardner.

11.4.1 What is intelligence?

What do we mean when we use the word **intelligence**? Do the words 'brainy', 'smart', 'bright' and 'clever' come to mind? Psychologists' definitions of intelligence range from 'intelligence is what intelligence measures' to definitions such as 'a psychological potential to solve problems or to fashion products that are valued in at least one cultural context'.

intelligence has no agreed definition — some definitions include: 'the ability to learn and solve problems' and 'the capacity for logic, understanding, self awareness and creativity'

There are so many definitions because intelligence cannot be directly observed. Therefore, psychologists rely on observations of behaviour that they believe to be associated with intelligence. However, intelligence does have many common aspects, such as the ability to learn from experience, to reason, to solve problems, to deal with people and objects, and to adapt effectively to an environment.

It is generally accepted that intelligence seems to include a general ability that underlies a wide variety of human behaviour, and also includes other more specific abilities — memory, reasoning, use of language and numeracy — that are probably independent of one another.

In the past, research on intelligence focused on designing and implementing intelligence tests to calculate IQ scores; however, more recently, research does not rely so heavily on intelligence tests.

A major reason for this is the recognition that intelligence is broader than what those tests assess. There has been a shift towards studying how people solve a problem rather than what their answer actually is.

It is always fun to do an intelligence test to find out your IQ, though. Just remember that there are a lot of problems associated with these tests — so you shouldn't take the results too seriously. The average IQ is 100 (a range from 90 to 109). A genius is classified as someone with an IQ of more than 145.

FIGURE 11.9 Intelligent is often used interchangeably with 'smart' or 'brainy'. However, there are many different definitions of intelligence.

ACTIVITY: Explore different IQ tests — what they measure and how they are used

The most common types of IQ tests are:
- Stanford-Binet Intelligence Scale
- Universal Nonverbal Intelligence
- Differential Ability Scales
- Peabody Individual Achievement Test
- Wechsler Individual Achievement Test
- Wechsler Adult Intelligence Scale
- Woodcock Johnson III Tests of Cognitive Disabilities.

CASE STUDY: Mensa

Mensa is an organisation for people with an IQ in the top 2 per cent of the population. It accepts people of all ages and professions, and in Australia, around one third of Mensa's members are children. Seven of them are aged under four. The Academy Award-winning actress Geena Davis is a member, as is Jean Auel, the bestselling author of many books including Clan of the Cave Bear and Valley of the Horses.

11.4.2 Gardner's theory of multiple intelligences

One current theory of intelligence was proposed by a psychologist named Howard Gardner. He proposed that we do not have just one intelligence; we have a variety of intelligences. Everyone has a combination of each of these intelligences, but in different quantities. This theory explains individual strengths and weaknesses.

Table 11.2 describes each of the intelligences proposed by Gardner.

It is important to know which intelligences we score high, medium and low on. This knowledge enables us to enhance our strengths, and work on and challenge our weaknesses.

Did you know that even identical twins have different amounts of each intelligence? They are not as identical as we first thought!

TABLE 11.2 Types of intelligence

Type of intelligence	People who are strong in this intelligence:
Verbal/Linguistic 	• like to read, write and tell stories well • are good at memorising names, places and trivia and learn best by saying, hearing and seeing words • have highly developed auditory skills • think in words rather than pictures.
Logical/Mathematical 	• can manipulate numbers, quantities and operations, the way a mathematician does • like to do experiments, figure things out, work with numbers, ask questions and explore patterns and relationships • are good at maths, reasoning, logic and problem solving
Bodily/Kinaesthetic 	• can control body movements and handle objects skilfully • express themselves through movement • have a good sense of balance and eye–hand coordination (e.g. ball play, balancing beams)
Musical/Rhythmic 	• can produce and appreciate music • think in sounds, rhythms and patterns • are good at singing, whistling, playing musical instruments, recognising tonal patterns, composing music and remembering melodies
Visual/Spatial 	• tend to think in pictures and need to create vivid mental images to retain information • enjoy looking at maps, charts, pictures, videos and movies, and have a good sense of direction • are good at puzzles, reading, writing, sketching, painting, and creating visual metaphors and analogies (perhaps through the visual arts)
Intrapersonal 	• can self-reflect and be aware of their inner state of being • are good at recognising their own strengths and weaknesses • have an awareness of their inner emotions
Interpersonal 	• can relate to and understand others • try to see things from other people's points of view in order to understand how they think and feel • are great organisers and generally try to maintain peace in group settings and encourage cooperation

(continued)

Type of intelligence	People who are strong in this intelligence:
Naturalist 	• like to be outside, with animals, geography and weather; interacting with the surroundings • are good at categorising, organising a living area, planning a trip, preservation and conservation

Resources

eWorkbooks Multiple intelligences (ewbk-6435)

Types of intelligence (ewbk-6437)

assesson Additional automatically marked question sets

11.4 Exercise

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 4	Questions 2, 3	Question 5

Remember and understand

1. Define intelligence in your own words.
2. Name and describe each of Gardner's multiple intelligences in your own words.

Apply and analyse

3. Match each of the following professions to the most likely intelligence that would be required.

Professions	Intelligence
a. Athlete, ballet dancer, football player, gymnast, actor	**A.** Interpersonal
b. Counsellor, doctor, nurse, psychic	**B.** Logical/mathematical
c. Singer, musician, composer sound engineer	**C.** Visual/spatial
d. Poet, journalist, author, English teacher	**D.** Naturalistic
e. Zoologist, ecologist, scientist	**E.** Musical/rhythmical
f. Welfare worker, psychologist, nurse, teacher, police officer	**F.** Bodily/kinaesthetic
g. Maths teacher, accountant, engineer, scientist	**G.** Verbal/linguistic
h. Pilot, artist, tight rope walker, meteorologist	**H.** Intrapersonal

4. **a.** Brainstorm words that mean *intelligent*.
   b. Brainstorm and write down all the stereotypes used about intelligent people.

Evaluate and create

5. SIS Construct a PMI chart on the issues of measuring intelligence.

Fully worked solutions and sample responses are available in your digital formats.

11.5 Emotions and communication

LEARNING INTENTION

At the end of this subtopic you will be able to describe ten basic human emotions and be able to recognise that stress can be both a positive and negative experience and that developing emotional intelligence is an important factor in a successful life.

11.5.1 Experiencing emotions

We all experience **emotions** such as happiness, anger, fear, interest, disgust, surprise and sadness. We can also recognise these emotions in other people through their behaviours, their facial expressions, body language and what they say. Emotions are partly formed through experience and partly through maturation (genetics).

Emotion is defined as a complex pattern of bodily and mental changes, including physiological **arousal**, feelings, cognitive processes, and behavioural responses to a personally significant situation. Researchers believe that there are ten basic emotions that humans experience. Most of these emotions are present in infancy. It is suggested that all other emotions are combinations of these ten basic ones.

emotion a complex pattern of bodily and mental changes

arousal the state of being physiologically or psychologically activated

FIGURE 11.10 The ten basic emotions

11.5.2 Expressing emotions

Emotions can be expressed verbally as in 'I feel happy today' or nonverbally (communication without words). There are various types of nonverbal communication, including **kinesics** (body language) and **personal space**.

Kinesics

Kinesics is the use of body language, body movements, posture, gestures and facial expressions to communicate information. We all use body language to communicate our thoughts and feelings, although we may not be aware of it at the time. For example, when we are irritated, we may tense our bodies, press our lips together and turn away. Facial expressions are usually culturally universal. A smile in China means the same thing as it does in Australia.

Usually we are fairly good at reading other people's nonverbal communication. We read and interpret their facial expressions, body movements and posture.

We all have hard-to-control facial muscles that show our true emotions and that are hard to conceal. It is useful to be able to read feelings that 'leak through' via subtle facial expressions, body movements and posture.

- Lifting just the inner part of your eyebrows, which few people do consciously, reveals stress and worry.
- Eyebrows raised and pulled together signal fear.
- A pretend smile often continues for more than four or five seconds, by which time most real smiles have ended.
- Fidgeting may reveal anxiety or boredom.
- Lack of eye contact, looking up to the right and touching the face (especially around the mouth) are all well-known signs of lying.

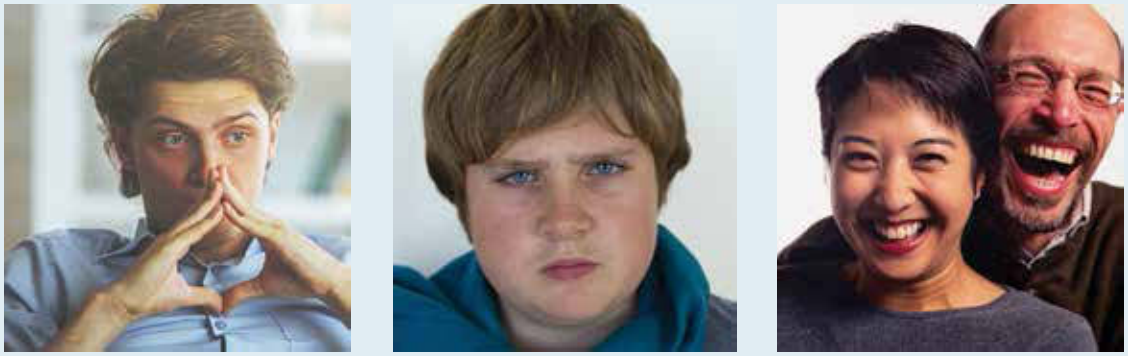
Next time you are speaking to someone, consciously pay attention to their body language. What are they saying nonverbally? Is it consistent with what they are saying verbally?

kinesics the study of body language as a type of non-verbal communication

personal space the space within a small distance of a person

ACTIVITY: Analysing facial expressions

Look at different emotional expressions to see which emotion fits which face. Look at the eyebrow and overall expressions of the face. What emotions are these people expressing, and how can you tell if the emotions are genuine?



Personal space

Personal space is another form of nonverbal communication. It is the small, invisible physical area immediately surrounding our body that is regarded as our own personal territory. The size of our personal space varies according to factors such as our cultural background, mood, who we are with, what we are doing and where we are. The four different zones of personal space are shown in table 11.3.

TABLE 11.3 The four different zones of personal space

Zone	Distance	Interaction activity	People allowed into the zone
Intimate	0–0.5 metres	Informal, physical contact may be involved with someone close, in public or private	Close family and friends, partner, girlfriend/boyfriend
Personal	0.5–1.5 metres	Informal in public; for example, at a party or at school	Friends
Social	1.5–3.5 metres	More formal talking; for example, with people at work who are not close friends	People you don't know very well
Public	More than 3.5 metres	Formal talking with someone you don't know, perhaps in large groups or crowds	Strangers

DISCUSSION

Do you remember the social/physical distancing rules introduced during the COVID-19 pandemic? How did they make you feel? Do you have a different sense of personal space now, after living with these rules?

11.5.3 Stress

Stress occurs any time that we must change in order to fit in with an environment. However, not all stress is bad.

Lots of life experiences cause stress, including school pressures, relationship problems, financial issues, travel, sports, a new job, mountain climbing, starting new relationships and other pleasant events.

Your body reacts to stress in the same way every time. Your nervous system causes your body to be alert or aware of the environment. Signs of alertness include increased heart rate, respiration rate, blood pressure and dilation (enlarging) of pupils. Perspiration also increases, your mouth gets dry and your appetite decreases. Do these signs sound familiar?

Can you think of examples where feeling stress is appropriate, or even beneficial? Stress is the body's response to changes that create challenging demands. Many professionals believe that there is a difference between what we perceive as positive stress (eustress), and negative stress (distress).

ACTIVITY: Analysing stress

Many young people encounter large amounts of stress. In small groups, complete the following.

a. Brainstorm the kinds of stressful situations young people may encounter in their life. Write these situations onto small pieces of paper.
b. Divide the situations into three categories:
   i. Very stressful
   ii. Quite stressful
   iii. Slightly stressful.
c. Choose one stressful situation from each category.
d. Answer the following for each of the three stressful situations the group chose.
   i. Who could help a young person cope with this situation?
   ii. Would this situation be perceived as positive stress or negative stress?
   iii. Describe a strategy they may use to help young people cope with this situation.

11.5.4 Emotional intelligence

While one way to measure intelligence was through IQ testing, another category of intelligence that has become widely recognised is emotional intelligence (also known as emotional quotient or EQ). High emotional intelligence allows people to better understand, empathise and negotiate with people, and is typically strongly developed in people in leadership roles, as they have the ability to understand, interpret and manage their own emotions as well as the emotions of others. Emotional intelligence is divided into five broad categoriesas shown in the figure 11.11.

Interestingly, psychologists believe that levels of EQ are far more important for success in life, including career success, than IQ levels.

FIGURE 11.11 The five broad categories of emotional intelligence

Self-awareness	• recognition of one's own emotions and how they can be managed; this has strong links to ideas of self-worth and capabilities
Self-regulation	• the ability to take control of emotions as one experience them and is linked to trustworthiness, conscientiousness, adaptability and being open to new ideas
Motivation	• a desire to improve, or to show commitment, initiative or optimism
Empathy	• the ability to recognise other people's emotions
Social skills	• an ability to communicate effectively to manage conflict, build relationships for collaboration and cooperation, and to lead and inspire

on Resources

Interactivity Emotional intelligence (int-8134)

eWorkbook Emotions (ewbk-6439)

assesson Additional automatically marked question sets

11.5 Exercise

learnon

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Select your pathway

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

Remember and understand

1. What are the ten basic emotions?
2. The following are characteristics of the zones of personal space. Determine which zone is being described.

TABLE Zone of personal space

Description	Zone of personal space
Within a distance of 1.5–3.5 metres	
Friends are allowed into this zone	
Informal interactions in public	
Close family and friends are allowed into this zone	
Should be at a distance of more than 3.5 metres	
Formal interactions with people you are not friends with	

3. MC When does stress occur?
   A. Only when you are thinking about stressful things
   B. When we are in a familiar environment
   C. When we are being ourselves in an unfamiliar environment
   D. When we must change to fit in with an environment.

Apply and analyse

4. Is body language culturally universal? Explain how body language tells us about someone's emotional state.
5. How does EQ differ from IQ?
6. Explain how stress can be harmful and yet helpful at the same time.

Evaluate and create

7. SIS Research how stress management, exercise and relaxation can help someone cope with stress. Present your findings in a poster.
8. SIS Starting with the theme 'Emotions' in the centre, create a cluster map to sort the emotions below into positive ones and negative ones. You may add other emotions to your cluster map.
   Happy, sad, guilty, anxious, excited, pleased, apprehensive, confused, contented, bewildered, calm

Fully worked solutions and sample responses are available in your digital formats.

11.6 Sleep and sleep disorders

LEARNING INTENTION

At the end of this subtopic you will be able to recognise the two types of sleep (REM and NREM), be able to describe insomnia as a sleep disorder common across all age groups, and you will have learnt that sleep walking and nightmares are examples of a sleep phenomenon.

11.6.1 Types of sleep: REM and NREM sleep

Every animal, including humans, needs sleep. In fact, we sleep for one-third of our lives. Sleep is a very important, complex process involving two different types of sleep:

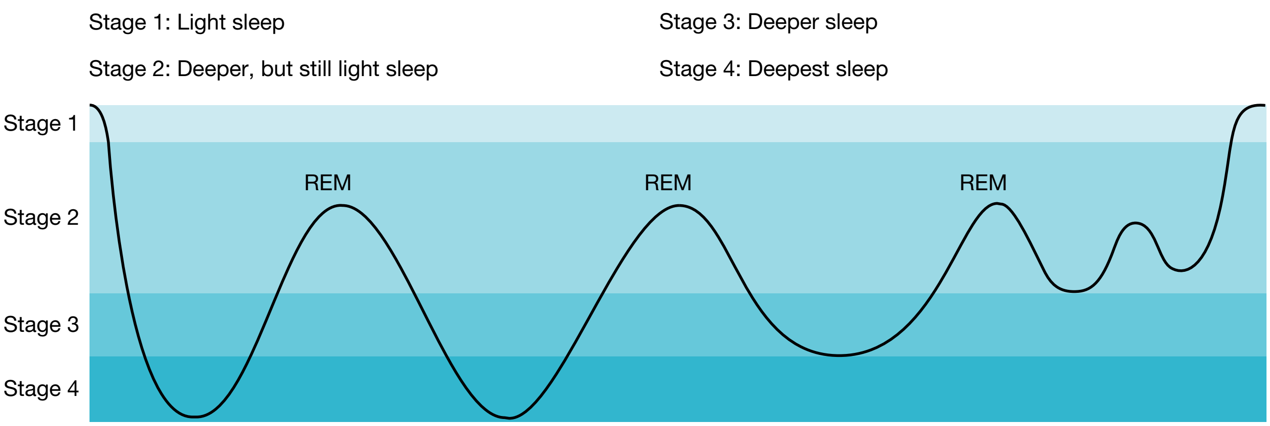
- **Rapid eye movement sleep (REM sleep)** occurs throughout the night, and is about 20 percent of our sleep time. This type of sleep involves the eyes moving around rapidly (while the eyelids are closed), muscle twitching and irregular breathing. It is during REM sleep that people dream. However, people remember their dreams only if they awaken during this stage of sleep. People sleep for a total of about 90 minutes each night in REM sleep, and periods of REM sleep get longer as the night progresses.

rapid eye movement sleep (REM sleep) a stage of sleep characterised by the repetitive, brief and erratic movements of the eyeballs under eyelids

- **Non-rapid eye movement sleep (NREM sleep)** is the remainder of a night's sleep (about 80 per cent of ou sleep time). In NREM sleep there is no observable movement of the eyes behind the eyelids, the body is still and there are no bodily movements. NREM sleep is divided into four stages, from a very light sleep (stage 1) to a very deep sleep (stage 4).

non-rapid eye movement sleep (NREM sleep) stages of sleep characterised by the absence of rapid eye movements

FIGURE 11.12 The four stages of sleep; REM sleep occurs after stage 2 throughout the period of sleep.



A sleep cycle starts by going from stage 1, to stage 2, to stage 3, to stage 4 sleep. In the first few cycles of sleep, people spend about 30 minutes in stage 4 sleep. They then go into stage 3 sleep and then stage 2 sleep. Sleepers do not usually go into stage 1 sleep again, but go into REM sleep, the second type of sleep. Most people have four to 5 sleep cycles each night. During the night, people go into stage 1 sleep only when they are falling asleep or waking up.

Today, smart watches can use our heart rate as a way to measure and record how much of our sleep we spend in each cycle. Tracking sleep cycles gives us good insight into the quality of our sleep.

TABLE 11.4 Characteristics of sleep stages

	Characteristics	What happens to the body?	If woken, how does the person react?	Is the person easily woken?
Stage 1	This is a light sleep, just after we 'doze off'.	The body relaxes, the heart slows down, body temperature drops slightly and breathing can become irregular.	Most people say that they were not fully asleep.	People are often still aware of external noises.
Stage 2	This is deeper, but is still light sleep.	The heart rate reduces further and there is a noticeable drop in body temperature.	Many people report that they were not fully asleep.	People can still react to loud or disruptive external stimuli.
Stage 3	This is a deeper sleep.	Heart rate and breathing tend to be slow, regular and relaxed.	People often report being asleep.	People are less likely to be affected by external stimuli.
Stage 4	This is the deepest stage of sleep.	There is a lower body temperature and a slower heart rate.	People take up to 10 minutes to become fully aware of their surroundings.	People are very difficult to wake at this stage of sleep.

11.6.2 Sleep disorders and phenomena

Sleep problems that disrupt the normal NREM–REM sleep cycle, including the onset of sleep, are called **sleep disorders**. Most can be successfully treated. **Insomnia** is one form of sleep disorder.

Sleep issues are common for all age groups. Studies show that 40 per cent of Australians don't get enough sleep. Approximately 30% of the adult population suffer from insomnia and 10% from chronic insomnia, making it the most common sleep disorder. This is followed by sleep apnea. In 2018, approximately 3–7% of men and 2–5% of women had sleep apnea, with over 100 million sufferers worldwide.

A **sleep phenomenon** is a normally-occurring behaviour at night that usually happens during childhood. Examples of sleep phenomena include sleepwalking, sleep talking, nightmares and night terrors.

sleep disorders problems that disrupt the normal sleep cycle

insomnia a sleep disorder whereby a person has difficulty either falling asleep or staying asleep

sleep phenomenon behaviours that occur at night including sleepwalking, sleep talking, nightmares and night terrors

symptoms physical or psychological features of a disease or disorder

somnambulism another word for sleepwalking

Insomnia

There are two types of insomnia:

i difficulty falling asleep (sleep onset)

ii difficulty staying asleep (sleep maintenance).

Insomnia is a disorder that results in a person not getting enough sleep each night. Some **symptoms** of this disorder include the failure to fall asleep within 30 minutes, wakening for longer than 30 minutes during the night, a consistently reduced amount of sleep and constantly feeling tired.

Psychologists believe possible causes of this disorder include stress and anxiety, pain, alcohol or drug use, jet-lag and shift work (a disruption to the normal sleep cycle). Possible treatments are medication (but not long term), relaxation and meditation, stress management and sleep hygiene practices. Sleep hygiene practices are regular routines carried out before going to bed, for example, having a warm shower, brushing your teeth and going to the toilet.

FIGURE 11.13 Insomnia is a sleep disorder that causes great distress.

Sleepwalking

Another name for sleepwalking is **somnambulism**. Somnambulism is walking while asleep and sometimes conducting routine activities such as dressing or going to the toilet.

Somnambulism occurs most often in children, but is not uncommon in adults during times of high stress. It occurs in stages 3 and 4 NREM sleep (deep sleep) and for 5–30 minutes at a time. Symptoms include poor coordination and incoherent language. People engaging in sleepwalking are usually unresponsive to the environment, and have a blank stare on their face. They rarely report remembering their night-time activities.

FIGURE 11.14 It is a myth that it is dangerous to wake someone who is sleepwalking. In reality, it is difficult to wake sleepwalkers because they are in a deep sleep, but it is not dangerous.

Nightmares

A nightmare is an unpleasant dream with content that is frightening and upsetting to the dreamer. Nightmares are remembered vividly, and happen during REM sleep. Common themes in nightmares are helpless terror, threatening situations, escaping and falling. Many people wake during their nightmare because of the upsetting content. The body is stationary, and paralysed (during REM sleep), and there is no indication whether the dream has pleasant or frightening themes. Nightmares occur more commonly in children than adults, and females are twice as likely to have nightmares as males. Nightmares happen at times of high stress, fatigue or personal trauma; however, experts are not entirely sure why people have nightmares.

ACTIVITY: Researching narcolepsy

Research narcolepsy. Find out the symptoms, causes and treatment of this disorder.

on Resources

Weblink Sleep Health Foundation

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11.6 Exercise

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Select your pathway

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

Remember and understand

1. What is the difference between REM and NREM sleep?
2. What is the difference between a sleep disorder and a sleep phenomenon?
3. When do nightmares and sleepwalking usually occur?

Apply and analyse

4. What is a sleep phenomenon? Name and describe one sleep phenomenon.
5. The following are characteristics of the four stages of sleep. Decide which stage is being described.

TABLE Characteristics of the different stages of sleep

Sleep characteristic	Stage of sleep
Body temperature is low and heart rate is slow	
People are often still aware of external noises	
If woken, people often report being asleep	
A light sleep, just after ‘dozing off’	
There is the first notable drop in body temperature	
People are very difficult to wake during this stage	

Evaluate and create

6. Describe the four stages of sleep. Draw a diagram to show the progression through each stage during the night and label when sleep disorders and sleep phenomenons are likely to occur.

Fully worked solutions and sample responses are available in your digital formats.

11.7 Psychopathology

LEARNING INTENTION

At the end of this subtopic you will be able to describe different types of mental disorders, their symptoms and their treatments.

11.7.1 Symptoms, diagnosis and prevalence

In Australia, it's estimated that 45 per cent of people will experience a mental health condition in their lifetime. This may make people behave in a way that is unusual, abnormal or different to what is expected in society. Clinical psychologists investigate, diagnose and treat these behaviours. They are often signs or symptoms of underlying mental disorders or **psychopathology**. A mental disorder is a significant impairment in psychological functioning. These psychological problems can be grouped into broad categories with common symptoms.

There are three important terms that need to be understood when discussing mental disorders.

- *Symptoms* or signs are the characteristics that allow a psychologist to diagnose a mental disorder.
- A *diagnosis* involves putting a label on a set of symptoms. This is similar to what happens when you go to the doctor if you are feeling unwell. For instance, Sally goes to her doctor because she has a cough, runny nose and sore throat (symptoms), so the doctor labels or diagnoses her illness as a cold. Similarly, Jake goes to a psychologist because he is sad, has feelings of hopelessness and has trouble getting out of bed (symptoms). The psychologist may diagnose Jake as suffering from **depression**.
- The word **prevalence** refers to how common a disorder is within the community. *Prevalence* can be expressed as either a percentage or a proportion. For example, the prevalence of phobias is between 9–11% of the community, and one in every 100 people suffers from **schizophrenia**.

Phobias

The NIMH (National Institute of Mental Health) defines a **phobia** as an intense or irrational fear of something that poses little or no risk. Objects such as snakes, spiders, and confined spaces often serve as triggers for phobias. In most cases, people know that their fears are unreasonable or excessive but they are unable to control them.

Examples of phobias include:

- agoraphobia — a fear of open spaces; people with agoraphobia find it very difficult, if not impossible, to go to the letterbox or to go out shopping
- ablutophobia — a fear of washing or bathing
- acrophobia — a fear of heights.

Phobias can be associated with nearly any object or situation. Everyone has a few fears but these are not necessarily phobias. Common fears are a fear of heights, closed spaces, or bugs and crawly things. A phobic disorder differs from such common fears in that it produces overwhelming anxiety and a need to escape the object or situation. Phobias often interfere with normal daily functioning, which is when the help of a professional is enlisted to help the individual finds ways to successfully cope and deal with their phobia.

Symptoms of a phobia include: hyperventilation, vomiting, fainting, sweating uncontrollably, increased heart rate and shaking, as well as nausea and hot flushes. In extreme cases, people work very hard avoiding those objects that cause them fear.

psychopathology the scientific study of mental disorders

depression lasting and continuous, deeply sad mood or loss of pleasure

prevalence the percentage or proportion of the population that have a certain illness or disorder

schizophrenia a disorder that affects a person's ability to think, feel and behave clearly

phobia an intense or irrational fear of something that poses little or no threat

Recent statistics suggest that an estimated 19.3% of adolescents have a specific phobia, and an estimated 0.6% have severe impairment as a result of the phobia (NIMH, 2017). The prevalence of specific phobia among adolescents was higher for females (22.1%) than for males (16.7%).

Treatment of phobias include: therapy or **anti-anxiety drugs**. Therapies aim to associate the feelings of being calm and relaxed with the presence of the feared object, so eventually the person is no longer afraid of the object. A combination of therapies is usually successful in treating and curing phobias. Cognitive Behaviour Therapy (CBT), a form of psychotherapy, can help people change unhealthy ways of thinking, feeling and behaving by equipping sufferers with practical self-help strategies, greatly improving their quality of life.

DISCUSSION

Agoraphobia comes from the Greek words *agora*, which means 'marketplace', and *phobia*, which means fear; literally, fear of the marketplace. Consider the names of other phobias to work out their meanings.

Depression

Depression is a mood disorder that can affect a person's daily life, usually involving intense feelings of sadness, loss, and/or anger. According to Beyond Blue (2019), around 1 million Australian adults have depression, and over 2 million have **anxiety**, making anxiety the most common mental health condition in Australia. There are different types of depressive disorders, which include:

- Major depression — also known as depressive disorder, clinical depression, unipolar depression or depression. Symptoms include a low mood and a loss of interest or pleasure in usual activities for most days, and lasts for over two weeks. It can be classified as mild, moderate or severe.
- Melancholia is a severe form where the person will move very slowly and has a complete loss of pleasure in almost everything.
- Psychotic depression can include hallucinations, delusions (false beliefs), or paranoia.
- Antenatal and postnatal depression occurs during pregnancy (antenatal) or in the year following childbirth (postnatal). While many women experience the 'baby blues' in the period immediately following childbirth, depression is much longer lasting and can compromise the mother's ability to care for herself, her baby, or other members of her family.

FIGURE 11.15 Postnatal depression affects 16 percent of mothers in the first three months after childbirth

Bipolar disorder

Bipolar disorder is where the individual sufferer has extreme mood swings between **mania** (elevated mood) and depression (feelings of being sad and worthless), usually separated by days or weeks of normal moods. It was previously known as bipolar depression.

When the person is manic, they will typically be full of energy with thoughts and feelings racing. They may talk loudly, function on minimal sleep, lack inhibitions, take large risks and lose their temper easily. People going through a manic episode can find themselves in trouble because they may engage in alcohol and drug consumption, and expensive shopping sprees.

When a person is depressed, their symptoms include feeling sad, worthless, helpless; a withdrawal from social relationships; difficulty in concentrating; diminished interest in pleasurable activities; neglect of appearance; and decreased energy and motivation.

anti-anxiety drugs drugs that aim to inhibit anxiety by restoring the balance of certain chemicals in the brain

anxiety a natural and usually short-lived reaction to a stressful situation; a disorder whereby anxious thoughts, feelings and physical symptoms occur frequently and persistently, disrupting daily life

bipolar disorder a disorder whereby a person has extreme mood swings between mania and depression

mania an elevated mood involving intense elation or irritability

Bipolar disorder is usually experienced by individuals before age 30. Approximately 1.2 per cent of the Australian population is diagnosed with bipolar depression in a lifetime. Bipolar depression occurs equally in males and females and it is more likely to run in families. This suggests that genetic factors may be involved in bipolar disorder. Many people suffering from this disorder are treated using counselling drug therapy.

FIGURE 11.16 Ben Stiller suffers from bipolar disorder.

Famous people who have suffered from bipolar depression include Buzz Aldrin (astronaut), Virginia Woolf (author), Francis Ford Coppola (movie director), Axl Rose (singer in Guns N' Roses) and Ben Stiller (actor). After displaying mood swings from aggression to extreme happiness during the making of *Zoolander*, Ben Stiller was quoted as saying 'I have not been an easygoing guy. I think it's called bipolar manic depression. I've got a rich history of that in my family.'

on Resources

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11.7 Exercise

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Select your pathway

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

Remember and understand

1. What does the word prevalence mean? What is the prevalence of phobias?
2. What are the treatment options for phobias?
3. What is the difference between a fear and a phobia?

Apply and analyse

4. **SIS** Research the symptoms, prevalence and support available for one of the following disorders. Present your findings in a PowerPoint presentation.
   - Catatonic schizophrenia
   - Post-traumatic stress disorder

Evaluate and create

5. Organise a Mental Health Week in your school to promote acceptance of mental disorders among your schoolmates. You could include activities such as poster presentations about various mental disorders and organise guest speakers to give talks.
6. **SIS** **a.** Create a PMI chart on the issue of labelling people with mental disorders.
   b. Form groups of six and compare the charts.
   c. Divide the six students into two groups of three. One group of three is the affirmative side and the other group of three is the negative side.
   d. Develop arguments for or against the topic Labelling people with mental illness is dangerous.
   e. Debate the topic above in front of the class.

Fully worked solutions and sample responses are available in your digital formats.

11.8 Treatment of mental disorders

LEARNING INTENTION

At the end of this subtopic you will be able to describe the treatment of mental health conditions that are used today including psychological therapies, behavioural therapies and biomedical therapies.

11.8.1 Past treatments

One of the earliest explanations of abnormal behaviour related it to supernatural causes. People believed that anyone behaving differently was possessed by the devil or practised witchcraft. The treatment of demonic possession and supernatural behaviour included elaborate prayer rites, forcing the affected to drink terrible tasting concoctions and brews, flogging, drowning and starvation.

In the fourteenth century, people with mental disorders were put into asylums and were chained or tortured. The treatment of mental disorders has greatly changed since then.

Fortunately for mentally ill patients, treatment of mental disorders has changed substantially over time. Originally the mentally ill were housed in large mental asylums, but today patients are placed in home-like surroundings and have the service of physicians who are skilled in the treatment of the conditions

FIGURE 11.17 In the past, people were housed in mental asylums. One famous asylum or sanitarium was Kellogg's Battle Creek Sanitarium, in Michigan. This sanitarium was of the health spa/hospital variety. Kellogg's cornflakes were invented at this institution.

11.8.2 Present treatment of mental disorders

Only acutely ill patients need to be inpatients in psychiatric wards of hospitals. One major reason why patients are able to live among society, rather than being confined to hospitals as was the case in the past, is due to the development of drug treatments. These drugs have allowed patients to be released sooner and cope more effectively within the community.

Today, treatment of mental disorders occurs in two main ways: **psychological therapies,** such as counselling, and **behaviour therapy**; and biomedical therapies, such as drugs and medication. Psychologists tend to specialise in psychological therapies, and doctors and psychiatrists specialise in biomedical therapies.

Psychological therapies

Psychological therapies involve structured interaction (usually verbal) between a professional and a client with a problem.

There are different types of psychological therapies; the most common being cognitive and behavioural therapies.

Cognitive therapies assume that the way we think about things affects our feelings and behaviours. So, if we change what we think about issues that are causing us concern, then we can decrease the concern we are feeling. Cognitive therapists try various methods to teach people more constructive ways of thinking.

psychological therapies structured interaction between a professional and a client to help overcome psychological problems

behaviour therapy a type of therapy that aims to identify and help fix self-destructive or unhealthy behaviours

cognitive therapies types of therapy that aim to teach people more constructive ways of thinking

Instead of trying to alleviate distressing behaviours by resolving a presumed underlying problem, behaviour therapy applies well-established learning principles to eliminate the unwanted behaviour. For example, to treat phobias behaviour therapists replace problem thoughts and maladaptive behaviours with more constructive ways of thinking and acting. This type of therapy is called **systematic desensitisation**.

FIGURE 11.18 Counselling of patients may occur in hospitals, clinics or private practices.

Biomedical therapies

Another way of treating mental disorders is by physically changing the brain's functioning — by altering its electrochemical transmissions with drugs.

The most common drugs used to treat mental disorders are **antipsychotic drugs** (to treat schizophrenia), antianxiety drugs (to treat anxiety), and antidepressant drugs (to treat depression).

Along with cognitive and behavioural therapies and medication, the most important treatment for mental illness today is the acceptance and understanding of such illnesses by society. The federal government has implemented a National Mental Health Strategy that aims to:

- promote the mental health of the Australian community
- prevent the development of mental disorders
- reduce the impact of mental disorders on individuals, families and the community
- assure the rights of people with mental illness.

Other campaigns implemented by the government include Beyond Blue, Kids Help Line, Lifeline, and better access to psychiatrists and psychologists through the Medical Benefits Scheme.

systematic desensitisation a type of therapy that aims to desensitise people to their phobias

antipsychotic drugs drugs that treat mental disorders such as depression, anxiety and schizophrenia

on Resources

Weblink Beyond Blue

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11.8 Exercise

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Select your pathway

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

Remember and understand

1. Describe how people with mental disorders were treated in the past.
2. How are mental disorders treated today?
3. What are the three main types of drugs used to treat mental disorders today?

4. Identify whether the following are characteristics of cognitive therapies or behavioural therapies.

TABLE Characteristics of cognitive or behavioural therapies

Characteristics	Cognitive or behavioural therapies
Teaching people more constructive ways of thinking	
Changing what we think about issues to reduce concern	
Applying established learning principles to eliminate unwanted behaviour	
Using the assumption that the way we think affects our feelings and behaviours	

Apply and analyse

5. How has the development of drugs to treat mental disorders allowed people to live among society, rather than being hospitalised?

Evaluate and create

6. Beyond Blue is a government initiative aimed at educating the community about mental health. Use the Beyond Blue weblink in your Resources section to investigate two ways that the community is educated about mental health in young people. Present your findings in a brochure.

Fully worked solutions and sample responses are available in your digital formats.

11.9 Groups and social psychology

LEARNING INTENTION

At the end of this subtopic you will be able to describe what a group is, why people like to join groups and styles of different group leaders.

11.9.1 What is a group?

We like spending time with others, and feel lonely if we don't. Our social system is structured so that we are members of many different **groups**. We belong to groups such as family, friends, work colleagues, school, sporting teams, religious and community groups. We are also members of groups automatically on the basis of personal characteristics such as sex, age and nationality.

Sociology is the study of social life, social change, and the social causes and consequences of human behaviour. Sociologists investigate the structure of groups, organisations, and societies, and how people interact within these contexts. One construct they closely examine is groups and group behaviour.

FIGURE 11.19 People in a crowd at a concert do not all interact with each other. Are they a group or a collective?

group collection of two or more people who interact with and influence one another and who share a common purpose

Are two people waiting in line at the supermarket a group? What about the crowd at a concert? According to social psychologists, a group is any collection of two or more people who interact with and influence one another, and who share a common goal or purpose. Therefore, the two people in line at a supermarket are not classified as a group if they do not communicate with each other. Similarly, members of a crowd at a concert do not all communicate with each other, and so are not classified as a group either. However, members of the band they are enjoying are interacting together and are classified as a group. The two former examples are known as a **collective** — an assemblage of people who have minimal contact with each other.

Why do people join groups?

People join groups to meet their social needs and to feel a sense of connectedness or belonging with others. There are other reasons why social connectedness is important to us. One need is the desire to associate and be involved with others. This is known as **affiliation**. Affiliation tells us about other people's attitudes and feelings, and provides us with a source of information to which we can compare our own attitudes and feelings.

Another reason humans join a group is to give a sense of **self-identity**. Self-identity is a personal awareness of ourselves, or knowing where we 'fit in' in society.

People also join groups to perform tasks and attain goals that cannot be achieved as an individual. For example, the captain of a football team cannot win on his own. He needs his team-mates to play the match with him in order to win.

11.9.2 Leadership of a group

Within a group, one or more members often carry a higher level of power or status than other members. Status refers to the importance of an individual's position within a group. Leadership involves an individual or group with high power and status directing a group.

Leaders have a very influential role in society. They are often in powerful positions and can significantly affect the beliefs, attitudes and behaviours of the group members. There are three different leadership styles that leaders use to exert their power.

- **Democratic leadership** is balanced between being task-oriented and people-oriented. Democratic leaders encourage all group members to participate in decision-making. They support the opinions of the group and promote cohesiveness, attainment of goals and ownership of decisions. Group members are satisfied because they feel that their opinions are acknowledged by the group. As discussed earlier in this topic, good leaders typically have a high EQ.
- **Laissez-faire leadership** this is a person-oriented leadership style where leaders are friendly and helpful, but have no direct control over the group. Instead, the group members have the control. The leader supports the group and wants them to have a good time — regardless of the outcome. This type of leadership is ineffective as goals are seldom reached, but group members are happy because their opinions are heard.

collective a collection of two or more people who do not interact with all other members of the collection

affiliation the human need for involvement and belonging to a social group

self-identity the personal awareness of one's self and where they fit into society

democratic leadership a balanced approach to leadership that allows group members to participate in decision making

laissez-faire leadership a person-oriented approach to leadership style whereby the leaders are friendly and helpful but do not have direct control over the group

FIGURE 11.20 Hitler (left) and Stalin (right) both employed an autocratic leadership style. They both made many decisions that affected the lives of Europeans and the rest of the world.

- **Autocratic leadership** this is a task-oriented leadership style where the leader makes the decisions for the group and has complete control of them. These leaders emphasise the importance of completing the task through the use of rewards and punishment. Often, individual members are dissatisfied because their opinions have not been heard. People who have employed this type of leadership include Hitler, Stalin and **cult** leaders.

autocratic leadership a leadership style whereby the leader makes all decisions and has complete control

cult a social group defined by intense belief and devotion to unusual religious or spiritual beliefs

CASE STUDY: Cults

A cult is led by an all-powerful and charismatic leader who is seen as the guiding spirit. Members of a cult are devoted to the leader, an idea or object. A cult usually has a religious basis, separates itself from the rest of society, and it may abuse the rights of the members.

A cult controls its members in different ways. These forms of control include: not allowing members to think for themselves apart from the group, allowing them to accept only what they are told, breaking relationships with friends and relatives outside the group and forcing them to unquestioningly submit to the group's teachings and directions — breaking their own free will. This control of members may occur by means of intimidation and the heavy use of guilt.

One of most infamous cults of recent times is Aleph, formerly known as Aum Shinrikyo. Aum Shinrikyo was responsible for a poisonous gas (sarin) attack on the Tokyo subway in 1995, which killed 13 people and injured thousands more. Senior members of the cult responsible for the Toyko gas attack received the death penalty. It is a doomsday cult that predicts the end of human civilisation except for members of the cult. While it has a belief system with elements of Buddhism, Hinduism, Christianity and the writings of Nostradamus, it has been designated a terrorist organisation by many countries. It is currently under surveillance by the Japanese government.

FIGURE 11.21 Shoko Asahara — founder of the Aleph (formerly Aum Shinrikyo) cult

on Resources

eWorkbook The ten best songs, ever! (ewbk-6441)

assess on Additional automatically marked question sets

11.9 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. What is the difference between a group and a collective?
2. What are the three leadership styles?
3. MC Which of the following is least likely to be classified as a group?
   A. A queue of people waiting to enter a concert
   B. Your class at school
   C. People stuck in an elevator for two hours
   D. Six teachers sitting in the staff room talking
4. MC Which of the following is least likely to be classified as a collective?
   A. Spectators at the AFL Grand Final
   B. People in a cinema watching a movie
   C. People stuck in an elevator for two hours
   D. People sitting in a hospital waiting room
5. How do cult leaders exercise their control?

Apply and analyse

6. Think of an example, other than the ones already mentioned, for each leadership style.
7. Explain how belonging to a group, such as a peer or sporting group, may have an important effect on a young person's sense of personal identity.

Evaluate and create

8. Research a cult such as the Manson Family on the internet. Identify how the members were coerced into the group and any other interesting information you can find.
9. SIS Create a PMI chart of the autocratic leadership style.

Fully worked solutions and sample responses are available in your digital formats.

11.10 Forensic psychology

LEARNING INTENTION

At the end of this subtopic you will be able to describe the role of a forensic pathologist in solving crimes and why lie detector tests are not allowed as evidence in Australian courts.

11.10.1 What is forensic psychology?

Do you like watching crime shows on television? These shows demonstrate how evidence is collected and how crimes are solved. The actual collection of evidence is done by scientists, but forensic psychologists also play an important role in the apprehension of perpetrators (catching the person who committed the crime).

Forensic psychology involves applying psychological knowledge and principles to legal issues. Forensic psychology investigates many aspects of crime, such as the reliability of evidence and eye-witness testimony, the role of human memory, decision-making, particular group decision-making (as in juries), and questions of the general credibility of witnesses.

What do forensic psychologists do and where do they work?

The work undertaken by a forensic psychologist is varied and may include: working with the police; building criminal profiles; assessing a criminal's state of mind and whether they are sane or not; assessing whether the person is mentally

forensic psychology the application of psychological knowledge and principles to legal issues fit to enter a plea (guilty or not) or stand trial; giving advice or an expert opinion to a court; assessing and treating people who are the victims of crime or witnesses of crime; providing treatment to offenders in prison; assessing the **dangerousness** of an offender (that is, whether they are likely to re-offend or not); and conducting research in areas of forensic psychology, such as personality characteristics of stalkers, jury behaviour and so on. Forensic psychologists usually work with the police at jails or in law courts.

Dangerousness

Forensic psychologists may need to determine if a person is dangerous or not. Dangerousness describes the likelihood of a person committing a serious act of violence, with little provocation. Assessing dangerousness means making a prediction about whether the person will be violent in the future.

FIGURE 11.22 Forensic psychologists help police create a criminal profile of an offender.

Criminal profiling

Another role of a forensic psychologist may be to provide a criminal profile of a perpetrator. Criminal profiling is a technique used to assist in the identification and apprehension of a likely offender for a particular crime. A criminal profile is a portrait or picture of a particular offender: the physiological characteristics such as sex, race, body build, height, weight, left or right handedness; psychological characteristics such as intelligence level, personality, aggressiveness; and personal details such as employment status, socio-economic status, marital status, clothing preference, where they live, and car type or preference.

Sometimes when police are investigating the death of someone, they notice that behaviours or clues are similar to a past murder. They are then able to link the murders. Someone who kills multiple people over time is known as a serial killer.

11.10.2 Serial killers

The leading authority on serial killers is the FBI, the United States Federal Bureau of Investigation. The FBI has studied serial killers methodically and has compiled vast amounts of information concerning the killers themselves, their methods, and their motivations on a criminal profiling database.

Personality characteristics that seem to be more common in serial killers, compared to other people, include impulsiveness, low self-esteem, poor social skills, competitive and aggressive behaviour, a lack of remorse and guiltlessness. An inherent sadistic nature is another part of the serial killer psyche, along with a fascination for violence, injury and torture.

dangerousness the likelihood of an offender to commit a serious act of violence with little provocation

11.10.3 The polygraph

In some countries, a polygraph (commonly called a lie detector) is used to determine if an accused person is telling the truth or not. It is often the role of a forensic psychologist to administer the **polygraph**.

FIGURE 11.23 During a polygraph test, galvanic skin resistance is measured, which reflects the amount of sweat on the skin. The more sweat on the skin, the higher the arousal and the less resistance it has to electrical currents.

People tell lies and deceive others for many reasons. Most often, lying is a defence mechanism used to avoid trouble with the law, a boss or authority figures. Sometimes you can tell when someone is lying, but other times it may not be so easy. Polygraphs are instruments that monitor a person's physiological reactions. These instruments do not, as their nickname suggests, detect lies. They can only detect whether deceptive behaviour is being displayed.

A polygraph instrument measures a person's arousal. Arousal refers to how alert or aware someone is of the environment. A person's heart rate, blood pressure, respiratory rate and electrodermal activity (sweatiness, in this case of the fingers) are measured and compared to normal levels. The more aroused someone becomes when asked about a crime, the more likely the person is lying.

Results from the polygraph are not allowed as evidence in Australian courts because it does not measure lies. Other conditions such as nervousness, stress, headaches, muscular problems and even the common cold can cause an increase in a person's arousal. Polygraphs can also be cheated.

polygraph a machine that attempts to detect deceptive behaviour by measuring arousal

CASE STUDY: How to cheat the polygraph test

One way of cheating the polygraph test is by hurting yourself — by stepping on a pin, clenching a muscle very tightly or biting your lip — when asked questions. The experience of pain also increases arousal, so the person operating the polygraph machine may think the person is just a highly anxious person, rather than a lying murderer!

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11.10 Exercise

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. Describe the role of a forensic psychologist.
2. What is the difference between a forensic psychologist and a forensic scientist?
3. MC Where do forensic psychologists work?
   A. In laboratories
   B. In doctors' clinics and hospitals
   C. In counselling services
   D. In jails or in law courts
4. Explain why the polygraph is inadmissible in Australian courts.
5. Decide whether the following are true or false. Justify any false responses.

Statement	True or false?
a. Forensic psychologists collect evidence at the scene of a crime.	
b. Forensic psychologists work with police while developing the criminal profile of a suspect.	
c. The best predictor of dangerousness is a history of violent behaviour towards others.	
d. The polygraph measures lies.	
e. The results of polygraph tests are inadmissible as evidence in a court of law in Australia.	

Apply and analyse

6. Research the role of forensic scientists, including ballistics experts, forensic serologists and forensic entomologists. What are the differences between each of these scientists?

Evaluate and create

7. SIS Create a PMI chart of the use of criminal profiling in the apprehension of perpetrators of crime. Compare your chart with that of the person sitting next to you.

Fully worked solutions and sample responses are available in your digital formats.

11.11 Review

Access your topic review eWorkbooks

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-6443	ewbk-6445	ewbk-6447

on Resources

11.11.1 Summary

Introducing psychology

- Psychology is a branch of science that investigates how our brain influences our thoughts, feelings and behaviours.
- Psychology is a growing science, investigating interesting ideas such as why serial killers kill, why we compete against each other and why stress makes us sick.
- Psychology is the systematic study of thoughts, feelings and behaviours.
- Psychologists can work in many areas, including sport, forensic, health, counselling, clinical, neuropsychology, academic, educational and organisational psychology.

The brain

- The outer layer of the brain, the cerebral cortex, is responsible for: problem solving, memory, personality, judging, planning, learning, logical reasoning and decision making. The cerebral cortex is divided into two halves called cerebral hemispheres.
- The left and right hemispheres have different specialisations but work together.
- The two hemisphere share information through the corpus callosum.

Intelligence

- Psychologists' definitions of intelligence range from 'intelligence is what intelligence measures' to definitions such as 'a psychological potential to solve problems or to fashion products that are valued in at least one cultural context'.

Emotions and communication

- Various types of nonverbal communication are possible, including kinesics (body language) and personal space.
- Stress occurs any time we must change in order to fit in with an environment.
- High emotional intelligence (EQ) allows people to better understand, empathise and negotiate with people. EQ is regarded as more important than IQ for success in life.

Sleep and sleep disorders

- Rapid eye movement sleep (REM sleep) occurs throughout the night. It involves the eyes moving around rapidly (while the eyelids are closed), muscle twitching and irregular breathing. People dream during REM sleep.
- Non-rapid eye movement sleep (NREM sleep) is divided into four stages, from a very light sleep (stage 1) to a very deep sleep (stage 4).
- Sleep problems that disrupt the normal NREM–REM sleep cycle, including the onset of sleep, are called sleep disorders. Most can be successfully treated. Insomnia is one form of sleep disorder.
- Sleep phenomenons are normally occurring behaviours and can include sleep walking, sleep talking, nightmares and night terrors.

Psychopathology

- Symptoms or signs are the characteristics that allow a psychologist to diagnose a mental disorder. A diagnosis involves putting a label on a set of symptoms.

- The word 'prevalence' refers to how common a disorder is within the community.
- A phobia is an intense, irrational fear and avoidance of an activity, a situation or a particular object.
- Bipolar depression is a depressive disorder where the individual sufferer has extreme mood swings between mania (elevated mood) and depression (feelings of being sad and worthless), usually separated by days or weeks of normal moods.

Treatment of mental disorders

- Today, treatment of mental disorders occurs in two main ways: psychological therapies, such as counselling and behaviour therapy; and biomedical therapies, such as drugs and medication.

Groups and social psychology

- In a collective, people do not all interact with each other. In a group, members interact with each other.
- Leadership involves an individual or group with high power and status directing a group.
- Democratic leadership is balanced between being task- and people-oriented.
- Laissez-faire leadership is a person-oriented leadership style where leaders are friendly and helpful but have no direct control over the group. Instead, the group members have the control.
- Autocratic leadership is a task-oriented leadership style where the leader makes the decisions for the group and has complete control of them.

Forensic psychology

- Forensic psychology involves applying psychological knowledge and principles to legal issues.

11.11.2 Key terms

affiliation the human need for involvement and belonging to a social group
anti-anxiety drugs drugs that aim to inhibit anxiety by restoring the balance of certain chemicals in the brain
antipsychotic drugs drugs that treat mental disorders such as depression, anxiety and schizophrenia
anxiety a natural and usually short-lived reaction to a stressful situation; a disorder whereby anxious thoughts, feelings and physical symptoms occur frequently and persistently, disrupting daily life
arousal the state of being physiologically or psychologically activated
autocratic leadership a leadership style whereby the leader makes all decisions and has complete control
behaviour therapy a type of therapy that aims to identify and help fix self-destructive or unhealthy behaviours
bipolar disorder a disorder whereby a person has extreme mood swings between mania and depression
cerebral cortex the outer layer of the brain, which processes information and is linked to memory and problem solving
cerebral hemispheres the two halves of the cerebral cortex, both responsible for different ways of thinking
cognitive therapies types of therapy that aim to teach people more constructive ways of thinking
collective a collection of two or more people who do not interact with all other members of the collection
control group a group of participants within an experiment who are not exposed to the variable being tested, and are used to compare to the experimental group
corpus callosum the part of the brain that connects the two hemispheres, allowing them to function interactively
criminal profiling a profile detailing the physical and behavioural traits of a criminal that is used by detectives and police
cult a social group defined by intense belief and devotion to unusual religious or spiritual beliefs
dangerousness the likelihood of an offender to commit a serious act of violence with little provocation
democratic leadership a balanced approach to leadership that allows group members to participate in decision making
depression lasting and continuous, deeply sad mood or loss of pleasure
emotion a complex pattern of bodily and mental changes
experimental group a group of participants within an experiment who are exposed to the variable being tested
forensic psychology the application of psychological knowledge and principles to legal issues
group collection of two or more people who interact with and influence one another and who share a common purpose
insomnia a sleep disorder whereby a person has difficulty either falling asleep or staying asleep
intelligence has no agreed definition — some definitions include: 'the ability to learn and solve problems' and 'the capacity for logic, understanding, self awareness and creativity'
kinesics the study of body language as a type of non-verbal communication
laissez-faire leadership a person-oriented approach to leadership style whereby the leaders are friendly and helpful but do not have direct control over the group
mania an elevated mood involving intense elation or irritability

non-rapid eye movement sleep (NREM sleep) stages of sleep characterised by the absence of rapid eye movements
personality the combination of characteristics or qualities that form an individual's distinctive character
personal space the space within a small distance of a person
phobia an intense or irrational fear of something that poses little or no threat
polygraph a machine that attempts to detect deceptive behaviour by measuring arousal
population the entire group of people who are being studied from which a sample is selected
prevalence the percentage or proportion of the population that have a certain illness or disorder
pseudosciences fields that are not sciences, despite having scientific sounding names or claiming to be scientific
psychiatrists medical doctors that specialise in the diagnosis and treatment of medical illness
psychological therapies structured interaction between a professional and a client to help overcome psychological problems
psychologists an expert or specialist in psychology
psychology the systematic studies of thoughts, feelings and behaviours
psychopathology the scientific study of mental disorders
rapid eye movement sleep (REM sleep) a stage of sleep characterised by the repetitive, brief and erratic movements of the eyeballs under eyelids
sample a smaller group of individuals selected from a larger group that has been chosen to be studied
schizophrenia a disorder that affects a person's ability to think, feel and behave clearly
scientific method a systematic and logical process of investigation to test hypotheses and answer questions based on data or observations
self-identity the personal awareness of one's self and where they fit into society
sleep disorders problems that disrupt the normal sleep cycle
sleep phenomenon behaviours that occur at night including sleepwalking, sleep talking, nightmares and night terrors
somnambulism another word for sleepwalking
symptoms physical or psychological features of a disease or disorder
systematic desensitisation a type of therapy that aims to desensitise people to their phobias

on Resources

eWorkbooks	Study checklist (ewbk-6449) Literacy builder (ewbk-6450) Crossword (ewbk-6452) Word search (ewbk-6454)
Digital document	Key terms glossary (doc-35035)

11.11 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 7, 8, 9, 10, 12, 14, 18, 20	Questions 3, 4, 6, 11, 13, 16, 22, 23, 25	Questions 5, 15, 17, 19, 21, 24, 26

Remember and understand

1. MC Which of the following is NOT a behaviour?
   A. Blinking
   B. Going for a walk
   C. Laughing
   D. Having a toothache

2. **MC** A major difference between a psychologist and a psychiatrist is that:
   A. a psychologist is allowed to perform medical procedures whereas a psychiatrist is not
   B. there are fewer areas of specialisation in psychology than there are in psychiatry
   C. a psychologist is allowed to prescribe certain types of medication, whereas a psychiatrist can prescribe all types of medication
   D. a psychiatrist is allowed to prescribe medication whereas a psychologist is not.
3. a. Psychiatrists spend 6 years on average at university, while psychologists spend 11 years on average. True or false?
   b. Explain the differences in work carried out by psychologists and psychiatrists.
4. Why is astrology considered to be non-scientific?
5. Describe the role of an organisational psychologist.
6. What is the role of the corpus callosum in the brain?
7. **MC** Psychologists use the term personality to refer to an individual's:
   A. temperament, mood and ability to relate to others
   B. distinct mix of changing physical attributes, behaviour and thought patterns
   C. relatively unchanging, unique, psychological characteristics and behaviour patterns
   D. all of the above.
8. **MC** Gardner's theory of multiple intelligences proposes that everybody has:
   A. just one type of intelligence
   B. a combination of two different types of intelligence
   C. all of the intelligences but in different quantities
   D. different types of intelligences, except for identical twins.
9. **MC** In an adult, REM sleep constitutes approximately what percentage of the total time spent asleep?
   A. 20% B. 30% C. 40% D. 50%
10. **MC** __________ is the inability to get enough sleep.
   A. Pseudoinsomnia B. Hypersomnia C. Somnolence D. Insomnia
11. The cerebrum is divided into two halves — the left and the right cerebral hemispheres. These hemispheres have specialised functions.
   a. Name two functions of the left hemisphere.
   b. Name two functions of the right hemisphere.
12. Describe the two main functions of the central nervous system.
13. List two types of non-verbal communication. Give an example of each type.

Apply and analyse

14. **MC** The term dangerousness refers to:
   A. the likelihood of a person committing a serious act of violence
   B. the likelihood of a person stalking another person
   C. whether or not the alleged offender is able to understand what they have been charged with
   D. having a mental disorder or intellectual disability at the time of committing the offence.
15. **MC** Which of the following is least likely to be classified as a collective?
   A. The spectators at a cricket match
   B. The people in a cinema watching a movie
   C. Six people talking at a party
   D. People sitting in a tram

16. **MC** The type of work that may be undertaken by a forensic psychologist could include:
   A. enhancing sporting performance through mental skills training
   B. giving advice or an expert opinion to a court
   C. helping couples to communicate more effectively
   D. assessing an individual's career potential.
17. Which of the multiple intelligences would be important for people working as the following? Explain your response.
   a. Journalist
   b. Ballet dancer
   c. Ecologist

18. MC Forensic psychologists are most likely to be employed by:
   A. schools
   B. large corporate banks
   C. the police
   D. debt-collection agencies.
19. There are four zones of personal space; describe the size and the activities that might occur in the intimate zone.
20. Briefly describe two symptoms of insomnia.
21. True or false? Justify any false responses.
   a. Multiple murderers who commit crimes over time are called serial killers.
   b. The FBI collects and keeps many criminal profiles in a database that is used to solve other crimes.
   c. One way of cheating the polygraph is to put a pin in your shoe and hurt yourself when answering the irrelevant questions.
   d. The results of a polygraph can be used as evidence in Australian courts.
   e. The polygraph measures lies.

22. Describe how the polygraph works.
23. Describe any other methods of lie detection, besides the polygraph.
24. Investigate the mental disorder, depression. Answer the following questions:
   a. What is the prevalence?
   b. What are the symptoms?
   c. What is the treatment?
   d. What is the relationship between depression and suicide?
   e. How were mental disorders treated pre-nineteenth century?
   f. Name five drugs that are used to treat mental disorders.

Evaluate and create

25. People react differently to different stressful situations. Our interpretations about how well we can cope with a situation affect how well we actually deal with it. However, there are simple methods of reducing a difficult experience into a more manageable experience. These include stress management, relaxation, social support, counselling and aerobic exercise. Research how one of these may be used to reduce stress.
26. SIS There are many ways of testing intelligence. Use the internet to research two of these methods and create a Venn diagram to display their differences and similarities.

Fully worked solutions and sample responses are available in your digital formats.

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on Resources

eWorkbook Reflection (ewbk-3038)

teachon

Test maker
Create customised assessments from our extensive range of questions, including teacher-quarantined questions. Access the assignments section in learnON to begin creating and assigning assessments to students.

RESOURCE SUMMARY

on Resources

Below is a full list of **rich resources** available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

11.1 Overview

eWorkbooks

- Psychology eWorkbook (ewbk-6424)
- Student learning matrix (ewbk-6426)
- Starter activity (ewbk-6427)

11.2 Introducing psychology

Interactivity

- Gallery: Specialist areas in psychology (int-7051)

11.3 The brain

eWorkbooks

- Labelling parts of the brain (ewbk-6429)
- What are your strengths and weaknesses at school? (ewbk-6433)
- Investigating neurons (ewbk-6431)

Interactivity

- Labelling parts of the brain (int-8133)

11.4 Intelligence

eWorkbooks

- Multiple intelligences (ewbk-6435)
- Types of intelligence (ewbk-6437)

11.5 Emotions and communication

eWorkbook

- Emotions (ewbk-6439)

Interactivity

- Emotional intelligence (int-8134)

11.6 Sleep and sleep disorders

Weblink

- Sleep Health Foundation

11.8 Treatment of mental disorders

Weblink

- Beyond Blue

11.9 Groups and social psychology

eWorkbook

- The ten best songs, ever! (ewbk-6441)

11.11 Review

Digital document

- Key terms glossary (doc-35035)

eWorkbooks

- Topic review Level 1 (ewbk-6443)
- Topic review Level 2 (ewbk-6445)
- Topic review Level 3 (ewbk-6447)
- Study checklist (ewbk-6449)
- Literacy builder (ewbk-6450)
- Crossword (ewbk-6452)
- Word search (ewbk-6454)
- Reflection (ewbk-3038)

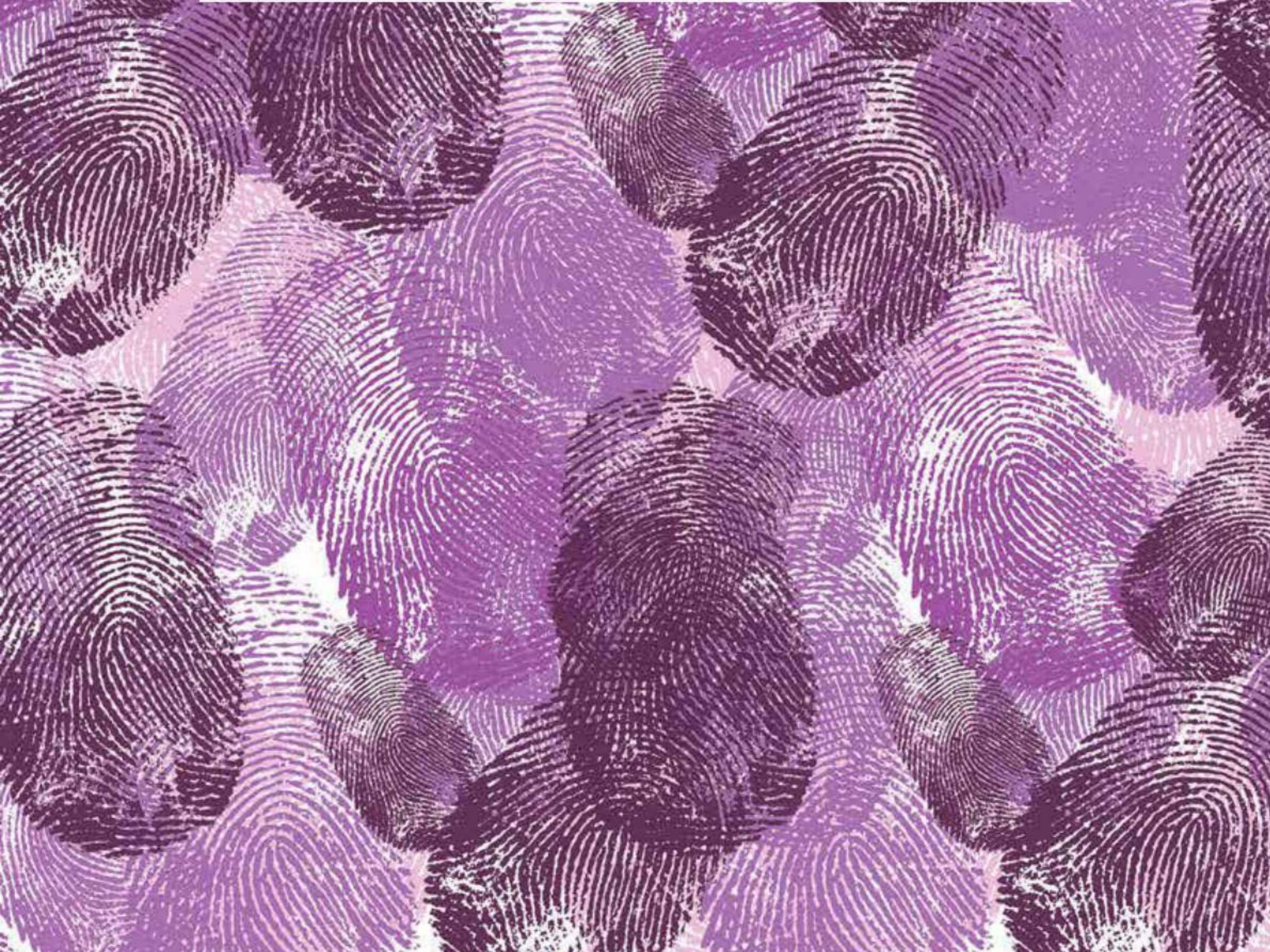
To access these online resources, log on to **www.jacplus.com.au**.

12 Forensics

LEARNING SEQUENCE

online only

12.1 Overview
12.2 *The Forensic Herald*
12.3 Who knows who dunnit?
12.4 Forensic toolbox
12.5 Discovering the truth through forensics
12.6 Clues from blood
12.7 Clues in hair, fibres and tracks
12.8 Life as a forensic scientist
12.9 Forensics and the future
12.10 Review



12.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

12.1.1 Introduction

Forensic ballistic investigators use the unique bullet grooves created by individual guns to make a match between bullets and guns. They look at the indentations in cartridge cases and identify them with the chamber marks in the gun they came from. If there is no suspect bullet or gun evidence, the entry point of a bullet hole can be analysed to determine the type and size of the gun, at what angle it was shot, and the minimum and maximum firing distance. Exit bullet holes are often larger than the bullet and can also give clues as to the type of gun used. Residue found in and around bullet holes is generally made up of gunpowder, lead, smoke and unburned particles. The clothing or material through which the bullet passed is handed over to investigators for analysis. It is microscopically examined and chemically processed to determine if there is a pattern of gunshot residue, which provides information on the order, distance and angle of the shots. All this may lead to a conviction!

FIGURE 12.1 Different guns create different bullet grooves that can be used as evidence.

on Resources

Video eLesson How a gun fires bullets in slow motion (eles-4218)

Watch this video to observe how bullets are fired by a specific type of handgun, observing how the bullet casings fly out. These can help provide evidence at crime scenes.

12.1.2 Think about forensics

1. If there is no body and no gun at a crime scene, what evidence remains to give clues about what happened?
2. What information can be found on a bullet?
3. How do police solve crimes with identical twins when they have the same DNA?
4. Some individuals are born with adermatoglyphia, in which they are born without fingerprints. Would these people be able to commit the perfect crime?
5. In a robbery, other than DNA evidence, what else might a forensics team search for?
6. How much DNA do you need to create a DNA profile?
7. Should the DNA and fingerprints of all individuals be kept in a database?
8. What is the chance you could be incorrectly convicted of a crime?
9. How might broken glass be important in solving a crime?
10. Why are some crimes unsolved despite all the advances in forensics?

12.1.3 Science inquiry

elog-0723

INVESTIGATION F.1

Recreating a crime scene

Aim

To recreate a crime scene and show some of the expected evidence that would allow the crime to be solved

Materials

- a large box or container
- equipment to create a crime scene including different fabrics, pieces of plastic (or rounded glass), cling wrap, cellophane and markers
- scissors
- sticky tape

Method

1. Read the excerpt below outlining a crime that has occurred:
   The victim was travelling down her street at 8:00 pm after a dinner with friends. It seemed the local hoons had been out and about, as there were skid marks on the road that were not there 2 hours earlier. Arriving home, the victim unlocked her front door, nothing amiss except a faint smell of cigarette smoke. Upon walking to her bedroom, she noticed that the window had been smashed, creating jagged edges and glass everywhere. Immediately she called the police, who asked if anything was missing. She went to her jewellery box, noticing her engagement ring was gone from its location, hidden away as it no longer fit. The police arrived at the scene and searched for clues as to who the perpetrator may have been.

2. Using the materials provided, create a diorama of the crime scene, including some of the evidence that may have been found at the scene. Use the information in the story and your imagination to help construct this.

Results

Draw a sketch or take a photo of your model. Label the different evidence at the crime scene.

Discussion

1. Summarise the evidence that may be used by the police for a conviction and explain why you placed each piece of evidence in the location you did.
2. Why would it be important for a forensics team to wear protective clothes while examining the scene?
3. How might the police use the evidence to determine who committed the crime?
4. How would police determine if there was only one person involved or multiple?
5. What features outside the house might be useful to help solve this crime?
6. From a search of the evidence, it seemed the thief only opened the jewellery box that contained the ring. What might this suggest?

Conclusion

Summarise how evidence is used by forensics teams to solve crimes such as robberies.

on Resources

eWorkbooks Forensics eWorkbook (ewbk-6494)
Student learning matrix (ewbk-6527)
Starter activity (ewbk-6528)

Practical investigation eLogbook Forensics Practical investigation eLogbook (elog-0735)

learnon Access and answer an online Pre-test and receive **immediate corrective feedback** and **fully worked solutions** for all questions.

12.2 *The Forensic Herald*

LEARNING INTENTION

At the end of this subtopic you will be able to explain how crime scenes are investigated and provide examples of evidence that can be found.

12.2.1 A report from *The Forensic Herald*

FIGURE 12.2 Shots exploded from the Lazy Lizard's Latte Café today, shattering the quiet streets of Ballarat.

DATE: THURSDAY, 22 NOVEMBER — WEATHER: WARM, SHOWERS

COFFEE SHOP SHOOT OUT: Investigations begin

Forensic investigators have begun investigations into a violent shoot out that claimed three lives and left the Victorian town of Ballarat reeling.

Police were called to the Lazy Lizard's Latte Café at 8 pm on Tuesday night, after a neighbouring resident, Ms Michael, heard shots coming from inside.

Sergeant Hurst gave a candid account of the scene, describing it as one of upheaval upon arrival.

'We found the three deceased people, a waitress and two patrons, all bound together with rope, behind the counter of the café. Each had been shot once. And we found traces of blood leading all the way out the door, and tyre marks in the street. So far eight bullet holes in the walls and two through the window have been identified, and investigators are searching for shells and casings as we speak. It was very eerie being the first person there because everything was very still and quiet, except for the ceiling fan that was blowing receipts all over the place, and a burning coffee pot.'

The entire street has been sealed off while investigators collect evidence, a process that could take another day.

'I can confirm that all of the deceased are known to have police records, and at this stage it seems the attack was a robbery as the cash register was found empty. We have no witnesses other than the neighbour who called us. She said that she heard at least six shots,' said Sergeant Hurst.

Blockades have been established at all the main roads leading out of Ballarat, and extra patrol cars are on the beat. Residents are urged to be aware of anyone acting suspiciously and to notify police about any possible information regarding the attack.

FIGURE 12.3 Evidence left at the crime scene, showing a bloody footprint

ACTIVITY: Map of the crime scene

In groups, brainstorm what you think happened at the Lazy Lizard's Latte Café and present your three key ideas to the class. Create an annotated map of the crime scene that includes the café, street and the possible location of evidence.

on Resources

eWorkbook How observant are you? (ewbk-6496)

assess on Additional automatically marked question sets

12.2 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Use the report from *The Forensic Herald*, and the details in this subtopic to answer the following questions.

Remember and understand

1. How many bullet holes have been found so far? Why do you think this is significant?

Apply and analyse

2. What evidence is there that indicates at least one other person was in the café at the time?
3. What evidence is there that could indicate the amount of time that passed during and after the attack?
4. Write down all the factors in this story that you think could be clues. Explain why they might be useful.
5. Match the following evidence that could be gathered from a scene with the information that could be found from it.

Evidence	Information
a. Blood traces	**A.** Fingerprints, lip prints, DNA
b. Tyre marks	**B.** Location of shooter, gun type
c. Bullet holes	**C.** Trace where it was purchased
d. Rope	**D.** Car types, direction
e. Café glasses, crockery and cutlery	**E.** Movement of the killer, DNA, blood type

6. What lead would you follow up first? Why?
7. What physical and mental traits do you think the perpetrator would need to carry out this crime?
8. What sorts of questions would you ask the neighbours during your investigations?
9. If all the victims have criminal records, what type of information do you think police will already have on them?
10. Explain why the entire street was sealed off during the collection of evidence.

Evaluate and create

11. SIS Write up a one-page report on your initial conclusions of what happened at the Lazy Lizard's Latte Café.

Fully worked solutions and sample responses are available on your digital formats.

12.3 Who knows who dunnit?

LEARNING INTENTION

At the end of this subtopic you will be able to identify different individuals involved in forensics and understand the difference between medical forensic scientists and forensic field scientists.

12.3.1 Forensic scientists

In Australia, there are two types of forensic investigators: police officers who are trained to collect certain **evidence** at a crime scene, for example, fingerprint and ballistics experts and photographers; and there are forensic scientists. Forensic investigators study the objects or evidence, and provide an expert opinion that can then be used in court.

Forensic scientists are usually university-trained professionals who work in their field of specialty and lend their skills to legal investigations. Forensic science is not a specific branch of science, but a general term for the many disciplines used in crime scene investigation.

evidence facts or information that can be examined to determine whether a proposition is true

The administration of forensic science is the responsibility of each state and territory. In smaller regions, where fewer police work at the stations, they carry out more forensic investigations themselves, while in larger areas such as cities, there are more staff who specialise in different fields. Most forensic scientists work in a number of laboratory, medical and field science situations.

12.3.2 Medical forensic scientists

Forensic biologist

Forensic **biologists** look at the **genetics** of those involved in a crime (figure 12.7). They look at blood types and conduct **DNA** profiling to identify people at the scene of a crime, and to match **suspects** to evidence.

Forensic chemist

Forensic **chemists** will be asked to analyse any substances found at the scene of a crime. They may be asked to establish exactly what a substance is, for example, what type of explosive has been used. If police suspect poisoning, they will call a toxicologist, a chemist who specialises in poisons, to determine what type of drug has been seized, or what poisonous residue has been found, in a coffee cup, for instance.

FIGURE 12.4 Examining DNA and blood up close is important in forensics.

FIGURE 12.5 Some widely different bullet casings from a database of bullets found at a crime scene.

Forensic odontology

Also known as forensic dentistry, these investigators study the dental evidence found at a crime scene and help identify unknown corpses (figure 12.6). Dental enamel is the hardest substance in the body so is often well preserved and can be compared to dental records. Clues can be provided as to the age and identity of a victim by comparing dental evidence to x-rays, dental casts and photographs. Forensic **odontologists** are called to the scene of mass casualties. They can also provide an assessment of bite-mark injuries.

Forensic pathologist

These investigators are licensed **pathologists** in charge of examining bodies to determine things such as the cause of death, wounds and injuries. It is the forensic pathologist who carries out the postmortem — a medical examination of dead bodies, to determine how a person died.

Forensic anthropologist

These specialists help identify bodies that are decomposed, burned or otherwise unrecognisable. They often work in criminal cases where there are only skeletal remains. By analysing the age of the bones and the marks on them, they can help establish the time of death, and the types of wounds sustained by a victim. Forensic **anthropologists** are often called upon to identify victims of mass disasters.

biologists scientists who study the science of life

genetics the study of genes

DNA a substance found in all living things that contains genetic information

suspects people who are thought to be guilty of a crime

chemists scientists who study the atoms and molecules that make up all substances

odontologists scientists who study the structure and diseases of teeth

pathologists people who study the causes and effects of diseases, examining samples for diagnostic or forensic purposes

anthropologists people who are experts in humans and human remains

FIGURE 12.6 A skull found at a crime scene can be identified using dental records.

FIGURE 12.7 This forensic scientist processes evidence in a laboratory equipped for DNA extraction.

Forensic psychiatrist

Forensic **psychiatrists** are medically trained doctors. They evaluate a person's mental state, both at the time of an offence and during their trial. They can also be called on to give their opinion about a psychological issue; are involved in caring for prisoners, particularly mentally ill offenders; and provide psychological profiles of unknown perpetrators.

FIGURE 12.8 The facial reconstruction of a victim is built up from a plaster cast of the victim's skull. This is then covered in clay to simulate the facial muscles.

Forensic psychologist

Forensic psychologists are not medical doctors, but are trained in **psychology**. They perform counselling and therapy for problems relating to depression, relationship breakdown and grief, for instance. They also assist in cases such as child custody disputes and child abuse. Like forensic psychiatrists, they can advise judges on the state of defendants and victims' mental health, and provide criminal profiles. They can give their opinions on **civil court** law cases such as workers' **compensation** and wrongful death suits, as well.

12.3.3 Forensic field scientists

Computer forensics

This is the investigation of home computers, office workstations, CDs and laptops. Investigators look at the data storage and processing equipment to determine if it has been used for illegal or unusual activities.

FIGURE 12.9 The role of a forensic field scientist

Forensic botanist

Botanists can use their knowledge to investigate evidence such as plants, seeds and soil to place a suspect at the scene of a crime. For example, soil from a different location could be found in a boot print at the scene. A pollen grain might be found within this soil that can then be traced back to a plant from a suspect's garden.

psychiatrists psychologists that are also qualified medical doctors

psychology the systematic study of thoughts, feelings and behaviours

civil court a court that handles legal disputes, not crimes

compensation money that is awarded to someone in recognition of loss or injury

botanists scientists who study the life of plants

Forensic engineering

This type of investigation is generally carried out for civil cases. Engineers look at materials and structures that do not operate properly. Most **engineering** disasters such as train derailments and aircraft accidents are subject to forensic investigation. For example, forensic engineers were involved at the start of 2020 when a Sydney–Melbourne train derailed at Wallan, leading to the death of the two drivers. Insurance companies also use forensic engineers to investigate **liability**. Appliances, industrial machinery and basic tools can all be investigated if they cause injury or property damage.

FIGURE 12.10 Forensic engineers explore disasters such as train derailments.

Forensic entomology

A forensic **entomologist** studies the life cycles of insects such as flies, which feed on corpses, to determine the approximate time of death. An entomologist can also determine whether a body has been moved to a different location, based on the types of insects found at the scene.

Flies are attracted to carrion such as human corpses. Different species of fly lay their eggs at different times and their larvae feed on different tissues. By studying the insect population of a corpse and the number and type of insects found on a body, as well as their stage of development, the time of death can be determined.

FIGURE 12.11 The population of insects in a corpse can be studied to determine the time of death.

CASE STUDY: Entomology at work

In 2000, Australian entomologist Dr James Wallman was called on to investigate the body of an African man found in a shipping container in Adelaide. Investigators worked out that the container originated on the east coast of Africa and travelled from Dar es Salaam, in Tanzania, to Durban and then on to Fremantle by ship. It was taken to Adelaide by train. The man had apparently tried to hitch a ride down the coast of Africa, but was trapped and died of dehydration, having only a small bottle of water with him. Dr Wallman found three species of African flies on the man's body, and inspected their stages of development. The indications were that a blowfly infestation occurred when the shipping container was near Durban, and that the death probably took place en route between Durban and Dar es Salaam.

engineering the field of science and technology that applies scientific principles to design and build structures

liability an obligation, responsibility, hindrance or something that causes a disadvantage

entomologist a person who studies insects

DISCUSSION

In small groups, discuss the pros and cons of each type of job involved in forensics. Of the different jobs in forensics, discuss in a group which job you would be most interested in and why.

Resources

eWorkbook Forensic scientists (ewbk-6498)

assesson Additional automatically marked question sets

12.3 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. MC What is a postmortem?
   A. A forensic pathologist
   B. The cause of death
   C. An examination of a witness
   D. An examination of a dead body
2. Name the two broad groups of forensic scientists.
3. Complete the following sentence by filling the gaps with the terms entomologists and botanists.
   __________________ investigate plants, seed and soil, whereas __________________ examine the life cycles of insects.
4. MC Which of the following forensic scientists examine dental evidence to identify victims?
   A. Entomologists
   B. Biologists
   C. Pathologists
   D. Odontologists

Apply and analyse

5. You have found traces of white powder in a wine glass at a crime scene. Who would you ask to analyse it, and what do you want to know about it?
6. What clues would the soil found on the bottom of a suspect's shoe give?
7. How can environmental factors, such as the weather or scavengers, affect the rate of decomposition of a corpse?

Evaluate and create

8. Create a Venn diagram comparing forensic psychologists and forensic psychiatrists.
9. SIS Research the work of a forensic scientist and find out about one of the cases they have been involved in. Write a report of this case, trying to ensure both qualitative and quantitative data is included.
10. SIS Research the average salary of all the different types of forensic scientists and create a bar graph to display this data.

Fully worked solutions and sample responses are available on your digital formats.

12.4 Forensic toolbox

LEARNING INTENTION

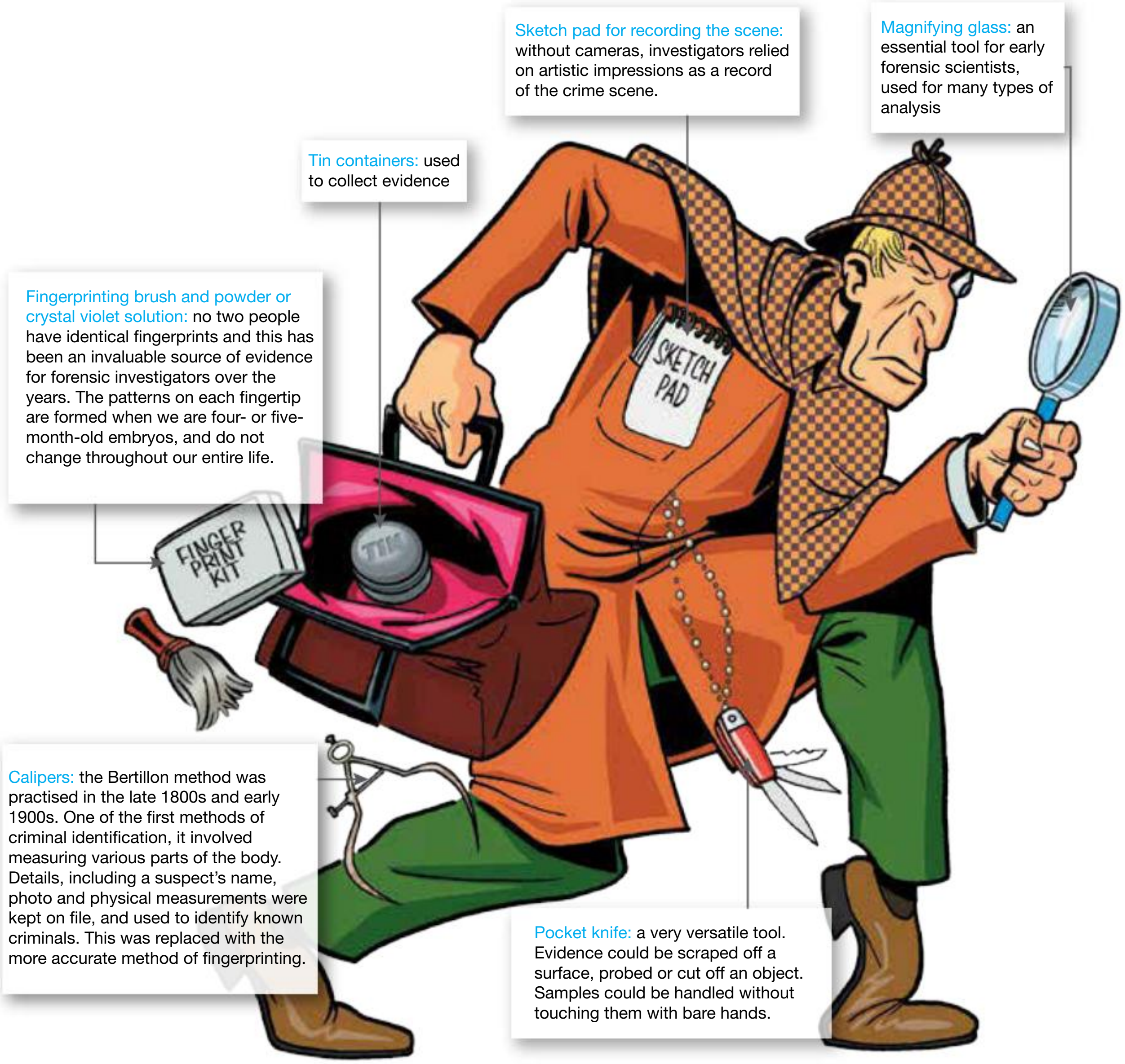
At the end of this subtopic you will be able to describe the different tools used in forensics and be able to understand how fingerprints are used in forensic investigations.

12.4.1 The old-school forensic toolbox

'Those were desperate times for policemen in a hostile country with unpaved streets and uneven sidewalks, sometimes miles from the police station, with little prospects of assistance in case of need ... It took nerve to be a policeman in those days.' So reported Chief Francis O'Neill of the Chicago Police Department in 1903.

A typical forensic toolbox used by crime scene investigators 100 years ago was very basic compared to those used today. Although many of the basic techniques and principles remain the same, modern technology has enhanced the efficiency and accessibility of equipment. However, human observation and intuition are still the most important tools in forensic science.

FIGURE 12.12 The old-school forensic toolbox is very different from what is currently used.



12.4.2 Analysing fingerprints

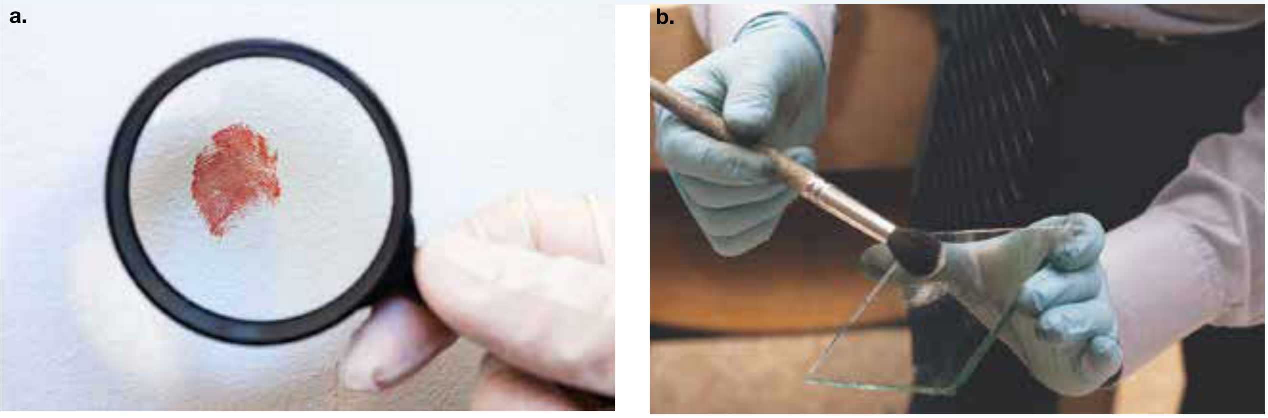
Every fingerprint is unique, formed by various friction ridges on the surface of fingers. The examination of fingerprints is known as dactyloscopy.

While the purpose of fingerprints is not well known, they provide vital clues in crime scenes, and have been used to help solve crimes throughout history. Crimes were solved using fingerprints starting in the late 1800s, but the uniqueness of fingerprints have been understood for an even longer period, with fingerprints used to authenticate government documents and contracts in ancient times.

There are two main types of fingerprint evidence that can be found in crime scenes:

- **Patent fingerprints** (or visible prints) are the easiest to see, often caused by visible substances such as blood or ink. An example of a patent fingerprint is shown in figure 12.13a.
- **Latent fingerprints** are invisible to the human eye and often caused by sweat and oil on the surface of the finger. These are the prints in forensic investigations that are often seen by dusting powder or chemicals over them to gain the print. An example of a latent fingerprint is shown in figure 12.13b.

FIGURE 12.13 **a.** Patent fingerprints and **b.** latent fingerprints



- Other fingerprints, such as plastic fingerprints (fingerprints embedded into a surface as a 3D impression, such as pushing fingers into a bar of soap or wax), may also be found at a crime scene.

While full fingerprints are ideal and provide a richer amount of evidence, often fingerprints at crime scenes are **partial prints**. Partial prints are a small and incomplete section of a full fingerprint. However, these can still be used in crime scenes and forensics.

patent fingerprints fingerprints that leave a visible mark on a surface

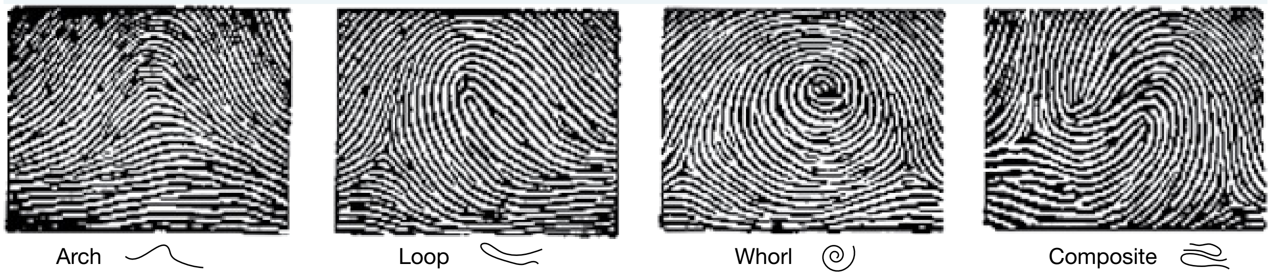
latent fingerprints fingerprints that are invisible to the human eye

partial prints a small and incomplete section of a full fingerprint

Identifying fingerprints

One of the earliest ways to explore fingerprints was through the examination of three main patterns: arches, loops and whorls. Sometimes, a composite of these may also be seen. These are shown in figure 12.14.

FIGURE 12.14 Different patterns seen within fingerprints



Loops are the most common feature seen in fingerprints, found in over 60% of all fingerprints. Whorls are the next most common feature seen, followed by arches and composites. Other patterns such a double loops and single loops may also be seen. Other unique irregularities (referred to as Galton's details) may also appear in fingerprints. This furthers the unique nature of fingerprints between individuals (and between each finger).

When collecting fingerprints from individuals, two types of methods are used: rolled fingerprints (through rolling the finger from one side to the other, as shown in figure 12.15b), and flat fingerprints. Both of these are usually taken to better verify the prints and ensure accuracy.

FIGURE 12.15 **a.** Both rolled and flat fingerprints are taken in crime investigations. **b.** An individual providing a rolled fingerprint

While fingerprints used to be checked manually, databases are now used to help find matching fingerprints more rapidly. An example of this is a database such as the Automated Fingerprint Identification System.

FIGURE 12.16 The Automated Fingerprint Identification System

elog-0723

INVESTIGATION F.2

Are you a loop, arch, whorl or composite?

Aim

To compare different fingerprint patterns

Materials

- an ink pad (black or blue)
- paper
- magnifying glass
- soap
- towel

Method

1. On the left side of the paper write *Left*, and on the right side, write *Right*.
2. Press all your fingers across the ink pad and then place the left-hand fingers on the left half of the page (ensure you use the full pads, not just the fingertips), beginning with the thumb and then the fingers.
3. Then do the same with the right hand on the right side of the paper.
4. After cleaning your hands, label each print: thumb, index finger, middle finger, ring finger and little finger.
5. You may wish to also do rolling fingerprints for each of your fingers and compare the results.

Result

Show each of your fingerprints, with labelled arches, loops, whorls and composites.

Discussion

1. Looking at the examples above, classify each of your prints.
2. Find out the most common type of fingerprint pattern in your class.
3. Which of your fingerprints are the most similar?
4. Is there anyone in the class with a similar fingerprint to you?
5. Identify two scenarios where the uniqueness of fingerprints can be used, other than in solving crimes.

Conclusion

Summarise your findings about fingerprints and how these are used in forensics.

DISCUSSION

Do you think all individuals should have their fingerprints kept on file? Outline the pros and cons of this and share your findings with others in the class. Does the opinion of others change your thoughts at all?

on Resources

Video eLesson Creating a rolling fingerprint (eles-4219)

ACTIVITY: Analysing your handwriting

A magnifying glass bends light rays (refraction) to make things look bigger. If you use a magnifying glass to look closely at a sample of handwriting, you will see more clearly the slant of the writing, the curls of the letters, the pressure on the paper, and the height and width of the writing. All these are characteristic of your handwriting. Look at your own signature under a magnifying glass.

Comment on:

1. The style of your writing — the spacing, slant, size and curls of the letters.
2. The pressure of your writing on the page.
3. The consistency in your writing — do the same letters look identical each time you write them?
4. Any other observations.

Compare your writing to others. What do you notice?

FIGURE 12.17 Handwriting can be used as evidence in many cases.

CASE STUDY: Ransom notes

In 1932, the son of legendary aviator Charles Lindbergh was kidnapped from his crib. Thirteen ransom notes were sent to the family and eventually $50 000 was handed to a man known as 'John' in return for a receipt and the details of where the child could be found. But the child was discovered dead.

A massive nationwide investigation was held, and one of the methods of investigation was a thorough analysis of the ransom notes. Almost all experts who examined the notes believed they were written by the same person. They thought that the writer was of German nationality and had spent some time in America. Eventually illegal German immigrant Bruno Richard Hauptmann was charged with the kidnapping.

FIGURE 12.18 One of the ransom notes left by the kidnapper

ACTIVITY: Identifying handwriting

Collect two pieces of paper and write the word 'forensics' on both pieces of paper. You should use the same handwriting for both. Your teacher should shuffle all the papers and hand two out at random to each person.

By analysing the handwriting, move around the room to try and find the matching pieces of paper for each of your samples written by the same person.

12.4.3 The modern forensic toolbox

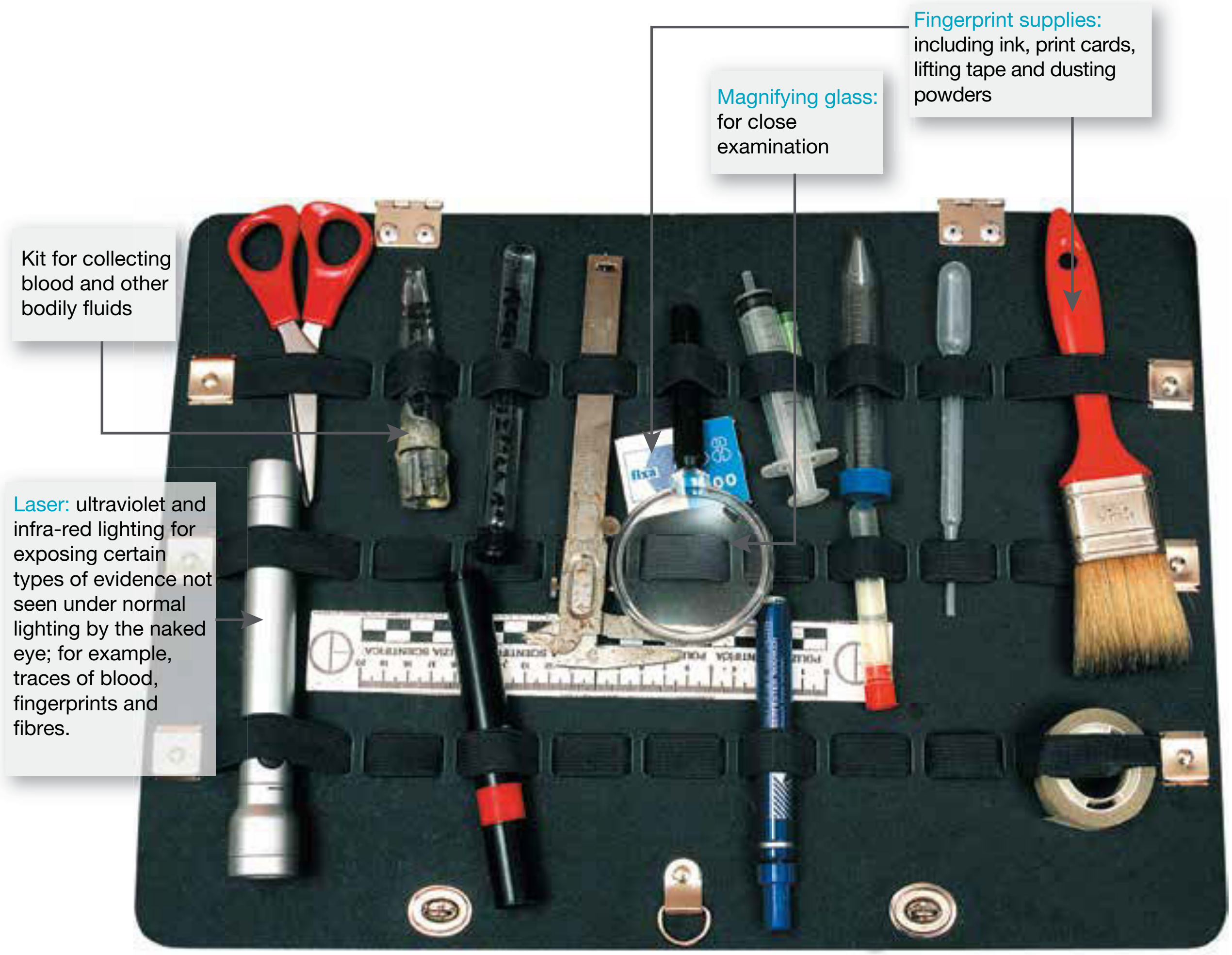
The modern forensic toolbox is more sophisticated and complex than the one used 100 years ago. Crime laboratories were set up around the world in the 1920s, and this meant a more controlled environment was required when collecting evidence.

Forensic kits, as shown in figure 12.19, also contain:

- a camera — to record the scene, with a photograph documentation kit marking evidence
- a torch
- a sexual assault kit — for collecting evidence in rape or assault cases, one each for the victim and the suspect, including medical history forms, clothing collection bags, containers for debris such as nail scrapings, slides and boxes for swab collection, paper disk for saliva sample, and blood vials
- tape — to seal off the crime scene area (blue and white police tape)

- disposable protective clothing, masks and gloves
- a notepad and pens — to record observations
- an entomology kit — for collecting and preserving insect evidence, including gloves, jars, ethyl alcohol, labels, a scalpel, a spatula and tweezers
- paper, plastic bags and glass tubes — for collecting evidence
- a cast kit — with putty and frames for making casts of tyres, footwear, and tool mark impressions
- tweezers and cotton swabs — for collecting evidence such as hair and **fibres**
- labels for evidence
- a hazmat spill kit — for handling hazardous materials.

FIGURE 12.19 Some of the tools used in more modern forensic kits — what else might be used?



12.4.4 Ultraviolet light

Ultraviolet light (UV light) is the band of wavelengths between visible light and x-rays on the electromagnetic spectrum. When exposed to this light source, many materials glow. Ultraviolet lights are used to identify many different types of evidence that cannot be seen in daylight, including fingerprints, **counterfeit** documents and **accelerants** in suspected **arson** cases. It can also be used to determine the fluorescent imprint that a **speedometer** needle leaves when determining how fast a car was going at the time of collision. The oil stains left on a road may assist in discovering the type of car driven as various oils glow differently under UV light.

fibres a thread that makes up a material such as a piece of clothing

ultraviolet light light that is invisible to the human eye but can be used to make certain substances glow

counterfeit an imitation or fake replica of money or a document

accelerants a substance that spreads fire easily

arson the criminal act of deliberately setting fire to property

speedometer the instrument that displays the speed of a vehicle such as a car or truck

FIGURE 12.20 UV light can be used to explore counterfeit money.

elog-0727

INVESTIGATION F.3

Exploring UV light

Aim

To explore what type of objects are fluorescent under UV light

Materials

- UV lights
- various objects including money (coins and paper), glassware, substances/chemicals (such as lemon juice and detergent) and any other objects

Method

1. Place samples of different substances, such as lemon juice and detergent, on a piece of paper (only small amounts are needed).
2. Use a UV light to investigate different objects and note down your observations.
3. Touch different objects explored and examine this under UV light. Can you see any evidence that you touched the object?

Results

Copy and complete a table similar to what is shown. Remember to add a title to your table.

Object	Observation

Discussion

1. What types of objects are fluorescent under UV light?
2. Why are UV lights used in solving crimes?

Conclusion

Summarise your findings about the use of UV lights in forensic investigations.

12.4.5 The polygraph

The polygraph, or 'lie detector', was invented in 1921 by medical student John Larson. Police began using the test in 1924 as a measure of testing if someone was lying. It works by placing a series of sensors on parts of the body that have involuntary stress reactions when an individual lies. When a person is asked questions, pens record measurements of pulses, perspiration, breathing and blood pressure on graph paper with each answer. Today, the sensors are much more accurate and the signals received are monitored electronically. But the polygraph still can't indicate that a suspect is lying, only that they have had a response to the question. However, modern polygraphs are very hard to fool!

FIGURE 12.21 Polygraph tests can explore a response to a question, which can signify that an individual may be lying.

ACTIVITY: Two truths and a lie

In small groups, play two truths and a lie (tell your teammates two true facts about yourself and one lie). See if others in your group can guess the lie. Have them write down a list of signs that made them think you were lying.

Repeat the activity, and see if you can adjust your behaviour to make your lie less obvious. Repeat this with all members of your group.

on Resources

eWorkbook Forensic toolkits (ewbk-6502)

assesson Additional automatically marked question sets

12.4 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

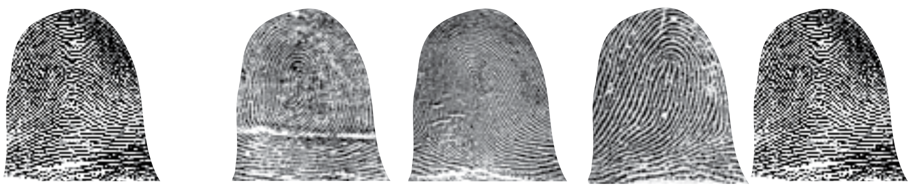
1. List three items a crime scene investigator might have carried one hundred years ago.
2. What is the Bertillon method?
3. Explain how the polygraph works.
4. List three items a modern crime scene investigator carries in their toolbox that an investigator didn't have one hundred years ago.
5. How is an arch fingerprint different from a loop?

Apply and analyse

6. Describe how ultraviolet light can be used to identify evidence. Provide three clear examples.
7. Investigators who relied on a magnifying glass one hundred years ago would have found it very useful. What evidence, besides handwriting, might they have examined with it?
8. Explain why you think fingerprint evidence would be more accurate than the Bertillon method.
9. a. Looking at the contents of the two forensic toolboxes, what methods are still in practice today and how have they changed?
   b. Predict some changes these methods may have in the future.

Evaluate and create

10. SIS Police fingerprinted four suspects. By comparing the fingerprints with the fingerprints found at the crime scene, decide which suspect was at the scene. Justify your response, referring to the different components of the fingerprints.



Fingerprint from scene | Suspect 1 | Suspect 2 | Suspect 3 | Suspect 4

11. Using online resources, investigate and report on:
    a. the pros and cons of the polygraph. Is it considered a reliable modern tool? Why?
    b. the Charles Lindbergh abduction case. What other piece of evidence left at the scene was a major factor in convicting Hauptmann? Explain the investigation.
    c. the tools that are contained in a Hazmat spill kit.

Fully worked solutions and sample responses are available on your digital formats.

12.5 Discovering the truth through forensics

LEARNING INTENTION

At the end of this subtopic you will be able to explain how DNA can be used in forensic investigations to solve crimes.

12.5.1 An old crime solved

The developments in forensic technology over the past one hundred years have helped some old mysteries be revisited, and solved.

In 1874, six prospectors became trapped in heavy snow at Lake City, Colorado. Only one prospector, Alferd Packer, made it back to civilisation. He told varying tales of how the others had died, and said that some had eaten the dead to stay alive. Packer looked fit and healthy and authorities were suspicious. Eventually he was convicted of five counts of manslaughter and sentenced to 40 years in prison. Since his conviction, there have been many rumours in the Wild West about what had really happened. Some believed Packer was innocent, while others believed he was guilty and that he had eaten his victims.

FIGURE 12.22 Alferd Packer, known as The Colorado Cannibal

In 1989, a forensic investigator exhumed the victims' bodies, hoping to determine what had happened. Packer had sometimes said that the men died of starvation or accidents, except for one who was shot. Using modern anthropological techniques, the investigator found that the bones showed the men had died violently, trying to defend themselves, and they had been de-fleshed by knives. Four of the skulls had been struck with a blunt object. The investigator's conclusion was that Packer's plea of innocence was entirely false.

12.5.2 Human codes

The cells that make up living things contain information. For the living thing it belongs to, this information is like a recipe. Information is stored in DNA (deoxyribonucleic acid), which is the individual genetic code of each person that determines their physical makeup. DNA is different for different people, but the DNA in all of the cells of any one person is the same. Only identical twins have the same DNA as each other.

FIGURE 12.23 A DNA profile is a representation of an individual's DNA, providing a 'genetic fingerprint'.

A single drop of blood found at a crime scene contains information about the person it came from. DNA profiling is a test that compares blood from a crime scene with that of a suspect. Actually, it's not just blood that can be used in this test. Body fluids, like saliva, hair roots and dead skin cells, can be tested as well. Humans drop hair and skin cells all the time and criminals often leave DNA evidence behind. Scientists can even trace the path of a piece of paper from the DNA left by people who have touched it.

DNA is usually used to help solve a crime in two ways. If a suspect has not been identified, biological evidence can be taken from a crime scene and analysed, then compared to the profiles of known offenders who are already in criminal DNA databases. If a suspect has been found, then their DNA can be directly compared to that found at the crime scene. DNA not only identifies criminals, but has been used in recent years to prove the innocence of some prisoners. There have been many cases over the past two decades where old DNA evidence, seized from a crime scene decades ago, has not matched the profile of the person in jail.

Kirk Bloodsworth was the first man in the US to be exonerated for a crime for which he was sentenced to death. In 1985, he was convicted of the sexual assault and murder of nine-year-old Dawn Hamilton. He protested his innocence, but at the time DNA testing was not used. In 1992, after DNA testing had become more common, prosecutors agreed to let the Forensic Science Associates examine a small stain found on the victim's clothing. They concluded it did not match Kirk's genetic profile, and in 1993 he was released from prison. One year later, the stain was checked against the DNA profiles of convicted sex offenders, and a man named Kimberly Ruffner was identified — a man Kirk had lifted weights with in the prison gym.

DISCUSSION

In groups of three or four, create a list of arguments for and against all people providing a DNA sample to keep on police records. Share your list with the rest of the class during a class discussion.

CASE STUDY: DNA profiling

Samples of blood, body fluids or skin that are collected from the crime scene are taken to a laboratory.

DNA is removed from the sample. Separating enzymes cut the DNA into small pieces at specific points.

The pieces of DNA from different samples are lined up across a jelly-like substance.

When electricity is passed through the sample, the pieces of DNA spread across the jelly-like substance. As the pieces spread, they form a pattern on the autograph.

DNA samples collected from a suspect go through the same process as the sample from the crime scene.

The autograph is for matching pieces of DNA from the different samples.

FIGURE 12.24 The pattern that DNA from the crime scene forms on a profile is compared to the patterns of DNA from the suspects.

12.5.3 The power of a testimony

Forensic scientists are regularly called to give evidence in court on what they think happened. Sometimes, interpretations of forensic evidence are incorrect. Below is an example of how the opinions of forensic scientists first sent a woman to jail, and then later released her.

FIGURE 12.25 A dingo was responsible for the death of Lindy Chamberlain's baby.

One of the most famous criminal cases in Australian history began with Lindy Chamberlain's claim, in 1980, that a 'dingo stole my baby'. Blood was found in the tent the child had been sleeping in, near Uluru, but no photos were taken. Police were suspicious of Lindy's claim, and in 1982 she was found guilty of murdering her baby. As there was no body found, no weapon, and no motive established, the case against her was built largely on the evidence of two forensic scientists.

- A forensic biologist stated she had found evidence of blood throughout Lindy's car. She took scrapings from the car, placed them on filtered paper and added a solution called orthotolidine, which is used to identify the presence of blood. They showed up bright blue and the biologist said this proved there was once blood all through the front of the vehicle, as well as on the zipper of a camera bag kept in the car.

- A forensic odontologist told the court that the damage to the jumpsuit found at the scene showed no evidence of either tooth marks or saliva from a dingo. He concluded that the jumpsuit had been cut with scissors.
- Lindy was found guilty and sentenced to life imprisonment. In 1986, the case was re-opened and two years of investigations followed. This time, different scientists came up with very different conclusions.
- Lindy's car was investigated again, this time by the Victorian Forensic Laboratory, who stated no traces of blood could be found. It was revealed that what the first forensic biologist thought was blood, was in fact sound deadener, a substance used by car manufacturers. The experiments found that orthotolidine, used by the first investigator, also picks up traces of copper oxide which is found in sound deadener.
- With the assistance of a microbiologist and a chemist, an investigator carried out months of experiments, finding that half the time dingoes tore fabric, and at other times they cut it, with their teeth.

Lindy was released from jail in 1986, and awarded $1.3 million in compensation. A movie was made in 1998 to tell the story. it was called 'Evil Angels' and starred Meryl Streep as Lindy and Sam Neill as her husband Michael.

on Resources

eWorkbook Using DNA evidence to solve crimes (ewbk-6504)

Weblink The story of Lindy Chamberlain — 40 years on

Video eLesson Comparing and matching DNA profiles (eles-4220)

assesson Additional automatically marked question sets

12.5 Exercise

learnon

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Select your pathway

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

Remember and understand

1. What type of forensic scientist looked at the bones of Alferd Packer's victims?
2. What is DNA?
3. Who would have the same DNA?
4. How is DNA used in forensic science?
5. What experiments did the first biologist and odontologist carry out in the Lindy Chamberlain case?

Apply and analyse

6. Kimberly Ruffner was a convicted offender whose DNA profile was already on file. What could police have done to exonerate Kirk Bloodsworth sooner?
7. What do you think the second set of forensic investigators did differently in the Lindy Chamberlain case?

Evaluate and create

8. SIS Research a miscarriage of justice that has been overturned by DNA evidence. present your findings to the class as a speech.

Fully worked solutions and sample responses are available on your digital formats.

12.6 Clues from blood

LEARNING INTENTION

At the end of this subtopic you will able to analyse blood patterns and will understand how the determination of blood type can help in forensic investigations.

12.6.1 Splat!

Even a tiny amount of blood left at a crime scene can give scientists and detectives valuable information. Bloodstains can tell investigators who was at the crime scene and what might have happened. Saliva and dead skin cells can also be traced back to an innocent bystander or a suspect.

FIGURE 12.26 Blood falling straight down from a low height leaves an almost perfect circular drop. When blood drops from a greater height, there is a ring of small drops around the central drop.

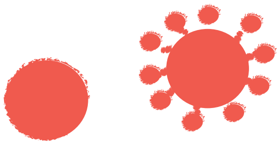
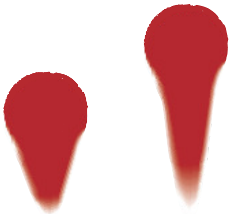
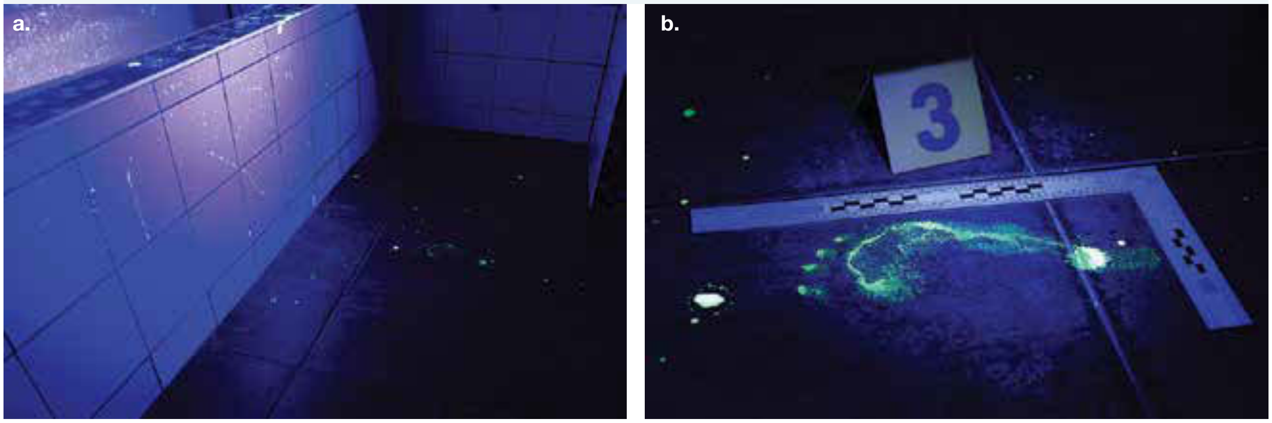


FIGURE 12.27 Blood that drops from an angle leaves a trail. The trail shows the direction in which the blood travelled.



Movies often show criminals cleaning up after a crime. They wash their clothes and wipe up blood spills. But forensic scientists can still detect traces of blood, even if it has been washed away. If crime-scene investigators believe that there may have been blood around, the area is treated with a fluorescent chemical such as luminol, which makes the blood fluorescent and visible under ultraviolet light. The treated blood is easy to see under ultraviolet light, as shown in figure 12.28.

FIGURE 12.28 UV light allows blood to be seen — **a.** stains of blood in a bathroom and **b.** a bloody footprint under UV light.



An arc of blood spatters forms when the victim pulls away from an impact. The number of arcs tells how many impacts there were on the victim. Forensic scientists can even tell if the **assailant** was left- or right-handed. The pattern of blood splatters provides lots of information about what occurred during a possible crime.

assailant someone who physically attacks another person

elog-0729

INVESTIGATION F.4

Exploring blood splatters

Aim

To observe how blood splatters appear in different conditions

Materials

- fake blood
- pipettes
- butchers paper (at least 6 sheets)
- ruler
- protractor
- gloves
- plastic knife
- clipboard
- white paper

Method

Before you begin, write a clear hypothesis for each part of this investigation.

Part A: Effect of height on blood splatters

1. Fill the pipette with fake blood.
2. Release a drop of fake blood onto the butcher's paper, from 10 centimetres above the surface, and label this.
3. Repeat this by releasing a single drop of blood from 20 centimetres.
4. Continue repeating step 2, increasing the height by 10 centimetres each time, up to 1 metre.
5. Label all your results, and sketch your findings in the results, as well as including a measurement for each.

Part B: Effect of angle of impact on blood splatters

6. Place a piece of white paper on a clipboard. Release a drop of blood from 30 cm above.
7. Angle the clipboard to 10° and release a drop of blood, labelling this drop as 10°.
8. Repeat this process, adjusting the angle of the clipboard each time by 10°, up to 60°.
9. Sketch and record your findings, measuring the size of each blood splatter.

Part C: Effect of speed on blood splatters

10. Dip a plastic knife in the fake blood.
11. Holding the knife in your hand, walk slowly along a long piece of butcher's paper, allowing the blood to drip, and sketch the pattern in your results.)
12. Dip another plastic knife in fake blood. Repeat the previous step (ensuring you are holding the knife at the same height), but walk at a medium pace.
13. Dip another plastic knife in the fake blood and walk quickly along the butcher's paper.

Results

1. Sketch your results for each investigation and outline your observations.
2. Record the size of each blood drop in an appropriate table.

Discussion

1. In each of the parts, identify the independent and dependent variable.
2. In each of the parts, identify the controlled variable.
3. Describe how a blood splatter is impacted by:
   a. the height of the drop
   b. the angle of the drop
   c. the speed of a walking individual.
4. What differences would you expect in the three above parts if a greater amount of blood was used?
5. Design an investigation that explores differences in blood splatters between right and left-handed individuals.
6. Sometimes, rather than blood splatters, handprints or footprints are instead found. Outline some factors that you think would affect handprints and footprints.
7. An individual has blood covering their hands and claps their hands to remove some of the blood. Sketch what you would expect to see in a blood splatter in this scenario.

Conclusion

Summarise your findings about the effect of height, angle of impact and speed on blood spatters.

12.6.2 Types of blood

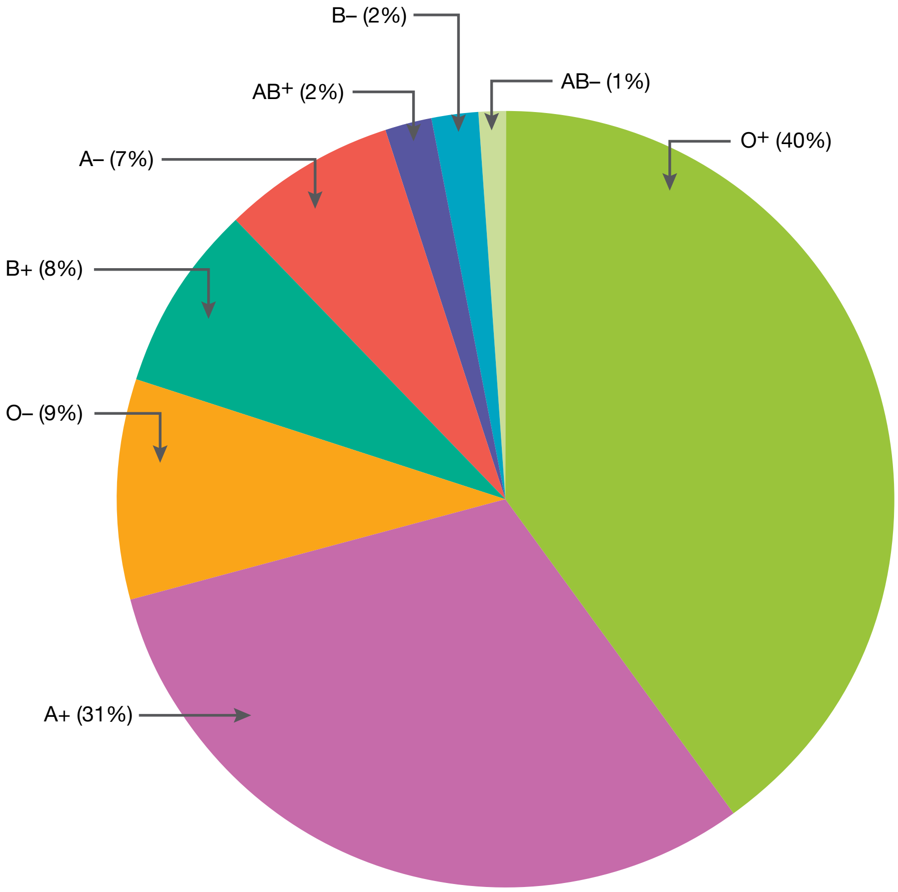
All human blood looks the same, but there are actually several different types of blood. In a laboratory, blood is tested to find out which of the four main groups — A, B, AB and O — it belongs to. Each of these groups can be further sorted into positive or negative. For example, a person could be A+ or A–, B+ or B– and so on.

Finding a blood type at a crime scene that matches the blood type of a suspect does not mean that the suspect was there. Many people share the same blood types. But comparing blood types does narrow the search. Blood can also be analysed for diseases or other features that link the sample more closely to a suspect.

If the blood types of samples from the crime scene don't match the suspect's blood type, then the suspect can be cleared.

FIGURE 12.29 You cannot tell the type of blood by looking directly at it.

FIGURE 12.30 Percentage of Australians with each blood type



DISCUSSION

Even though many people can have the same blood type, blood type analysis can still be useful in solving crimes. Discuss with those around you if you agree with this statement, and as a group come up with your answers and share with the others in the class.

on Resources

eWorkbook	Evidence from blood (ewbk-6506)
Weblink	Australian Police — Bloodstain pattern analysis
assess on	Additional automatically marked question sets

12.6 Exercise

learn**on**

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Select your pathway

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

Remember and understand

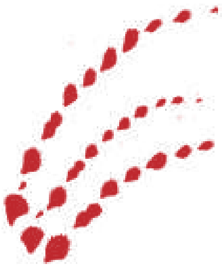
1. List the eight different blood types.
2. a. What is the most common blood type in the Australian population?
   b. What is the least common blood type in the Australian population?

Apply and analyse

3. Explain how blood at the scene could be used to show that a suspect was not at a crime scene.
4. A suspect has the same blood type as a sample found at a crime scene. Why is this not enough evidence to prove that the suspect was actually at the scene?
5. The chemical used to make bloodstains visible is called luminol. Suggest a reason for this name.
6. Use the internet to research how DNA profiles are produced. Find out the probability of two different DNA profiles matching.

Evaluate and create

7. **SIS** Research blood types globally.
   a. Create a pie graph, similar to the one shown in figure 12.30 showing the percentage of people with each blood type globally.
   b. How do these figures differ from the figures in Australia?
8. **SIS** The provided diagram shows the blood spatter pattern at a crime scene.
   a. Which direction was the blood travelling in when it hit the ground?
   b. How many blows did the victim receive? Explain your answer.
   c. Design an investigation that would allow you to observe the effect of direction and number of blows (or wounds) on a blood splatter.



Fully worked solutions and sample responses are available on your digital formats.

12.7 Clues in hair, fibres and tracks

LEARNING INTENTION

At the end of this subtopic you will be able to explain how evidence can be obtained from hair, fibres and tracks in forensic investigations.

12.7.1 Evidence

Wherever we go we leave some evidence behind and take some with us. Strands of hair or fibres from clothes, furniture and carpets can provide strong evidence that a suspect has been at a crime scene. Even the most careful criminals can't stop microscopic fibres sticking to their shoes. They may not realise that they have left a single strand of hair behind at a crime scene. Many hairs and fibres look the same, until they are examined under a microscope.

FIGURE 12.31 Even the tiniest hair or fibre can be found at a crime scene to assist in solving forensic cases.

12.7.2 Clues found in fabric

A forensic scientist compares fibres found at a crime scene, or on a victim, with those found on suspects' clothes, in their homes or in their cars. Under the microscope, a forensic scientist can also tell if fibres at the crime scene had been cut or torn. This helps them to piece together what may have happened during the crime. Fabrics are made from either natural or man-made fibres woven together. Some fabrics are a combination of different fibres. Under a microscope, each type of fibre looks different.

FIGURE 12.32 Acrylic fibres seen under a microscope

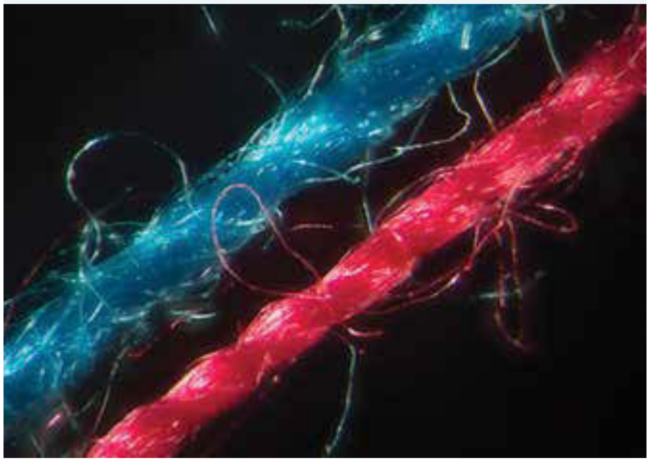


FIGURE 12.33 Nylon fibres seen under a microscope

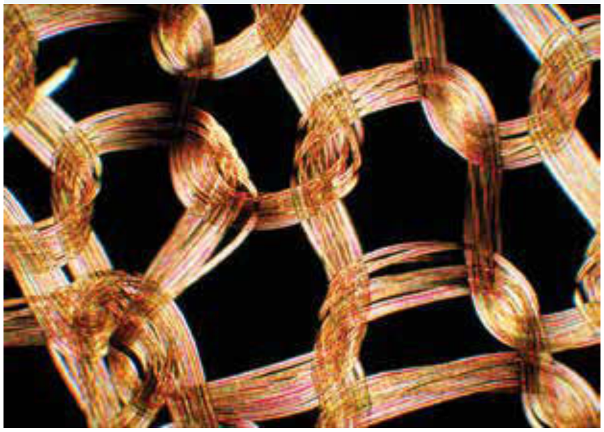


FIGURE 12.34 Merino wool fibres seen under a microscope

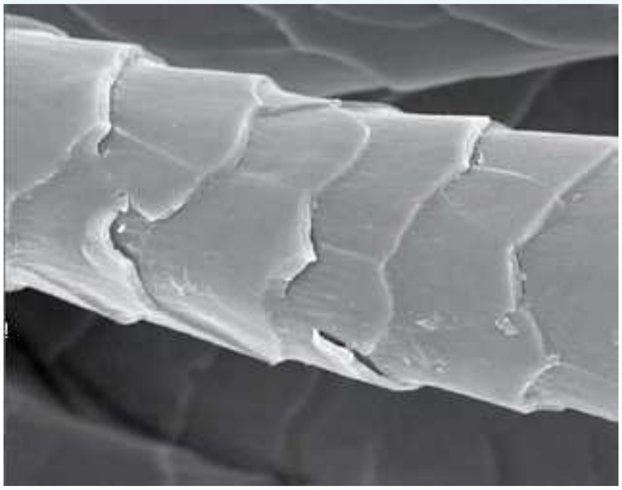
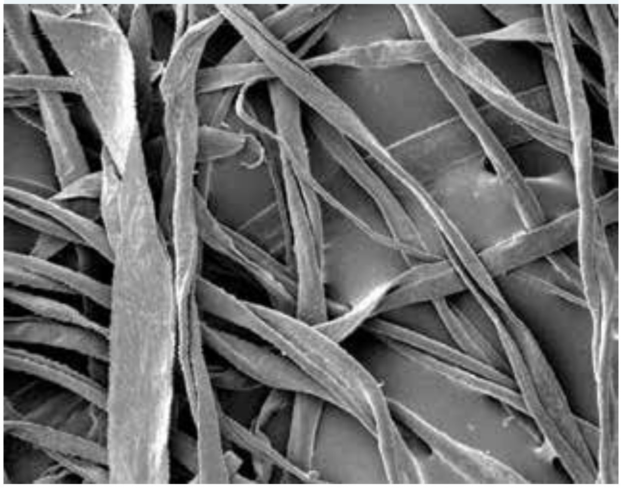


FIGURE 12.35 Cotton fibres seen under a microscope



12.7.3 Hair

By looking at hair samples under a microscope, forensic scientists can tell whether the sample belongs to a human or a different animal. The scaly, outer covering called a **cuticle** is different in each animal species.

With a microscope, the thickness, **coarseness**, colour and structure of hair can be checked. Scientists can even tell what type of shampoo has been used to wash the hair. A strand of hair found at a crime scene can be checked with a **comparison microscope** against hair from a suspect. A match between the hairs could be used as evidence to show that the suspect was at the scene.

Hair that has been pulled out can have skin or other substances stuck to it. DNA testing can link these hairs directly to a suspect.

cuticle the outer layer of hair
coarseness roughness
comparison microscope a microscope that allows two samples to be viewed simultaneously

FIGURE 12.36 Forensic scientists can tell if a hair sample has come from a person with curly, wavy or straight hair. Scientists can even sometimes tell the ethnic background of the person from their hair.

FIGURE 12.37 Human hair

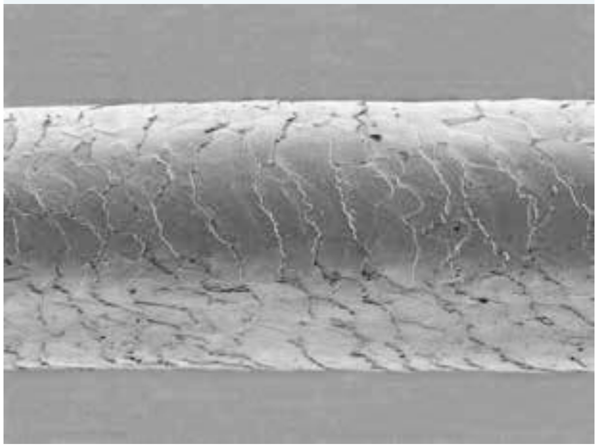


FIGURE 12.38 Dog hair

elog-0731

INVESTIGATION F.5

Comparing animal and human hair

Aim

To compare hair samples

Materials

- microscope, lamp and slides
- tweezers
- tape
- animal hair
- feather
- human hair
- samples of fibres

Method

1. Write a clear hypothesis for your investigation. What do you expect to see in each sample?
2. Set up the microscope.
3. Tape a sample of animal hair, human hair and a feather to the microscope slides. You may need tweezers to help position the hairs on the slides.
4. Repeat this with any other samples you may have.
5. View the slides under the microscope.

Results

Sketch your observations of each hair or fibre under the microscope, ensuring you include the magnification (10 x the magnification of the objective lens).

Discussion

1. What are the main features of your samples?
2. Explain some of the main differences you observe.
3. Explain any similarities you observe.
4. Compare your results with your peers. Did you have similar results? Justify why/why not.

Conclusion

Summarising the findings of your investigation, describe the differences between different hairs and fibres under the microscope.

12.7.4 Tracks as evidence

Footprints and shoe prints

Footprints and shoe prints can be used as evidence in crimes, providing information about the feet of an individual and about the shoes being worn.

More often than not, individuals are wearing shoes during a crime. Marks on the ground can help narrow down suspects in a crime — whether they be 2D markings, such as markings made by a dirty or bloody shoe, or 3D impressions, such as shoe prints across a muddy path. Some different examples of these are shown in figures 12.39 and 12.40.

Shoe print analysis can help determine the size of the shoe. This, in turn, can allow for an estimate on height. In 3D impressions, shoe prints can also provide information that can help estimate the weight of an individual. Similar to fingerprints, they can be classified as latent, patent (visible) or plastic impressions.

FIGURE 12.39 Shoe prints can have lots of variety.

FIGURE 12.40 Shoe prints can be 2D or 3D impressions.

While many shoes may leave similar shoe prints, other information can also be seen. For example, a missing aspect of a shoe print might be due to a bit of missing rubber or a rock lodged in the sole, which can help determine a suspect was at the scene of a crime.

Investigators often take photographs of shoe prints or make casts, allowing for the shoe prints to be explored in detail.

elog-0733

INVESTIGATION F.6

Analysing shoe prints

Aim

To investigate shoe prints left by different members of the class and identify who they belong to

Materials

- butcher's paper or white paper
- anything that can allow a print to be made, such as dirt, washable ink or rolled-out (flat) playdough (ensure it can come off your shoes so you don't leave marks everywhere)
- detergent
- paper towel

Method

1. Lay a piece of paper flat on the ground
2. Cover the base of one shoe with a substance that can make an impression.
3. Allow the print to dry and write a number on it. (Your teacher should assign each student a number; do not share your number with others.)
4. Carefully wash any residue off your shoe using detergent and paper towel.
5. Look at each shoe print around the room and try to identify each shoe.

Results

Create a results table similar to what is shown below to record your findings. Remember to add a title to your table.

Shoe print number	Individual whose shoe print I think this belongs to	Individual whose shoe print this actually belongs to
1		
2		

Discussion

1. Explain how you identified each shoe print.
2. How accurate were your findings?
3. What improvements would you make to help improve your identification?
4. Do you think a shoe print alone can be used to convict an individual? Justify your response.

Conclusion

Summarise how shoe prints can be used to determine a person's identity.

Tyre tracks

Tyre tracks leaving or entering the scene of the crime can often be used in forensics to help determine those present.

Similar to footprints, tyre marks differ between tyres. Differences may be due to:

- the age of a tyre
- the type of tyre
- the brand of tyre
- the type of car
- the tyre alignment on the car
- markings on the tyre (for example, some tyres may have dents or sections that have chipped off).

As well as this, the tyre tracks across all four tyres in a car may be slightly different, providing a unique profile for a specific car.

Tyre marks can be 2D marks, such as skidmarks across a road during a hit and run, or 3D impressions, such as when a car travels through a muddy field or snow. Similar to fingerprints, they can be classified as latent, patent (visible) or plastic impressions.

These tracks may be examined through searchable databases from different type manufacturers, which may help narrow down the type of vehicle used. Tyre reference prints may also be taken from a suspect's car and compared to tyres left at a crime scene.

FIGURE 12.41 Different tyre tracks may assist in forensic investigations.

DISCUSSION

A crime was committed at your school, and a student was found to have stolen money from the school canteen. On the floor of the canteen was a piece of hair, a piece of fibre and a shoe print. You are only allowed to investigate two of these to determine the culprit. As a class, discuss which two you would select and why.

on Resources

Weblink Different evidence used in forensics

eWorkbooks Exploring fibres, hair and tracks (ewbk-6508)

Read my lips (ewbk-6500)

assess on Additional automatically marked question sets

12.7 Exercise

learn on

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Select your pathway

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

Remember and understand

1. Why do hairs or fibres found at a crime scene need to be compared under a microscope?
2. MC Select the option that correctly completes the sentence. A cuticle is:
   A. the same in each animal species
   B. found only on humans
   C. the scaly, outer covering of a hair
   D. not useful in an investigation.

Apply and analyse

3. Identify the hair shown as either dog hair or human hair. Explain the reasons for your decision.
4. Describe what information footprints and shoe prints may provide at a crime scene.
5. An individual's car was found to match tracks that were seen leaving the crime scene.
   a. Would this be sufficient evidence for a conviction?
   b. What other evidence might police need to support a conviction?

Evaluate and create

6. SIS A detective found a small clump of human hairs at a crime scene. The hairs all showed evidence that they had been pulled out rather than falling out naturally.
   a. What might this suggest about what happened at the scene?
   b. What other tests could be applied to these hairs to help solve the crime?
   c. Write a brief report summarising the evidence and implications from this crime.
7. SIS The following shoe print was found in concrete outside a store where a robbery had occurred 30 minutes earlier.
   a. What conclusion may police draw from this?
   b. How many different shoe prints can be seen?
   c. The shoe prints belonged to a Mr P. Hollands. Write a script outlining the questions the police would ask Mr Hollands.

8. SIS Design an experiment to compare the properties of different fibres or fabrics. Properties that could be compared include:
   - strength
   - elasticity
   - absorption ability.

Fully worked solutions and sample responses are available on your digital formats.

12.8 Life as a forensic scientist

LEARNING INTENTION

At the end of this subtopic you will have a deeper understanding of the job involved for a forensic scientist and will be able to explain the misconceptions caused from crime TV shows.

SCIENCE AS A HUMAN ENDEAVOUR: An interview with forensic scientist Rob Hayes

Rob loves his job because . . .

There are three different areas I get a buzz out of. The first is discovering something that has real significance to a case; that could be finding some unique components of a paint layer and connecting it to a suspect. For instance, if somebody painted a car to disguise it, and painted it close to another car, then you might get overspray. Sometimes the colour pigments are rare, and restricted to a certain time period or model of a car. Repair paints are often very different to original finishes, and so they are easy to identify. Another major thing I like is the variety of work and being part of a team. I also love learning about the amazing forensic techniques and instruments that are being researched and developed — the futuristic stuff is so interesting!

FIGURE 12.42 Rob Hayes

Job title: Innovation coordinator for Forensics

Employer: Victoria Police Forensics Services Department

Qualifications: Bachelor of Science in Chemistry and Pharmacology

Responsibilities: Rob is a specialist in paint and its composition, and uses his knowledge of chemistry to analyse chemical trace evidence in police investigations. Rob's other responsibility is to coordinate research and innovation in new techniques and technologies across many disciplines, within the lab.

Another day at the office

Ah. A typical day, this varies a lot. A forensic scientist could be doing anything from an investigation in the lab; an example is washing a $5 note with solvents and analysing the material that comes off it for evidence of drugs. Or, they could spend the day writing up a statement or report.

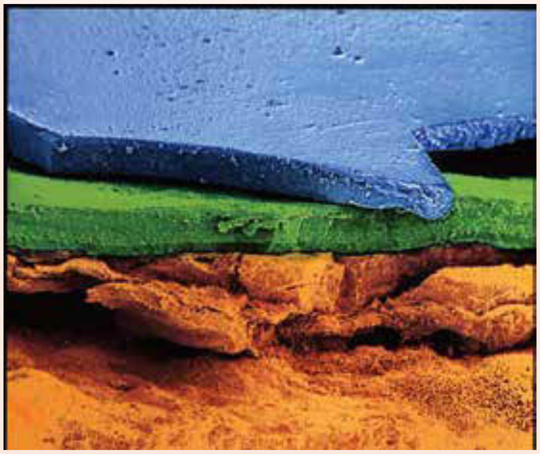
He can be called on to assist with all types of crimes

Over my career I have examined evidence from murders, assaults, thefts, burglaries, traffic incidents, drugs and re-birthed cars.

I've also worked on a number of hit and run accidents. In these cases I might have to match the paint marks left on the clothing of someone who has been hit by a car to a certain type of car.

I have been involved in cases where there have been a huge number of cars stolen. We work with investigators to decide on which areas of the cars may be critical to test, instead of analysing every part of all the cars. It's a team effort. While we might compare the original paint job with the new ones, the Vehicle Examination Unit will look at the mechanical side of things to decide if the car has been re-birthed.

FIGURE 12.43 An electron scanning micrograph of a flake of rusty paintwork; no metal is visible. The blue top layer is a layer of respray paint. It is badly bonded to the original paint, which has three layers of green and orange. The bottom orange crystalline region is rust. This evidence may help to convict a criminal of re-birthing a car.



When evidence comes into the lab, a number of forensic experts from different departments will talk to the person in charge of the case, and then we all work together to decide who needs to provide their expertise.

And he gets to use some high tech gear to do it

Most of our work is connected to microscopes because trace evidence can be very small. Tweezers and scalpels can often be used when recovering evidence.

Many of the more sophisticated instruments we work with require liquid nitrogen to keep them cool. These include infra-red spectrophotometers and a scanning electron microscope. These instruments can help us determine what types of components items contain, and some can also measure their colour.

What would you say to anyone thinking of a career in forensic science?

It's really interesting work, and when you find something you love, then it's not a job. If it is something you really want to do, then aim for it! With a little bit of luck and a lot of study and application, there's no reason why you can't succeed!

Is what you see on TV real?

There have been many TV dramas centred on forensic investigation. Detective work is a fascinating business. But is all we see true to life?

Too much responsibility

In most TV dramas, there are usually one or two detectives doing all the work. They attend the crime scene and seal it off, carry out spot tests and preliminary testing, collect samples, transport them to the lab, analyse the evidence or assist with a postmortem, interview the suspect and make the arrest! TV detectives would have a tough time convincing a court they were not **biased** with so much direct input into the case.

In real life, forensic experts are much more confined to their specialisation and often, the lab. The forensic photographer takes the photos, the fingerprint expert dusts for prints, and the forensic toxicologist looks for evidence of poisons or drugs. Each is a puzzle piece in the evidence that is presented to court, and often each forensic expert may not have knowledge of the whole case.

Speedy results

A lot of the scientific processes carried out by investigators in TV dramas are real to life. For example, the method of gas chromatography is used to separate components of mixtures to detect trace evidence. However, there are many complex, time-consuming experiments that don't make it onto TV. The nature of a TV drama is that the case must be solved within a short time frame, but real life examinations may require numerous tests. For example, if police suspect a person has been poisoned, a toxicologist must carry out many tests for things like pesticides and heavy metals, and then work by a process of elimination.

The tools used by TV detectives are usually realistic, although there have been a few errors. An example was in one recent episode of a TV drama, a character used fictional computer databases. They were able to punch in trace evidence, and match it against records in a few seconds. In real life, this is usually a much longer process.

biased not objective; taking personal experiences and ideologies into account

CASE STUDY: The CSI effect

The CSI effect is the public's interpretation of forensic science, based on popular TV shows. For example, there are concerns that juries are beginning to have unrealistic expectations of forensic scientists during court cases, after watching TV dramas. Another concern is that TV shows are raising awareness among criminals, who are wising up and covering their tracks by taking shell casings from crime scenes, and leaving fewer fingerprints!

FIGURE 12.44 Do TV shows affect forensic investigations and criminal activity?

ACTIVITY: Real crime TV?

Choose a TV forensic drama, and select an episode. Watch it carefully. Using the information in this chapter, and other resources, pick out as many differences as you can between real life and the TV show. Present your findings to the class through a PowerPoint presentation, explaining what each difference is, and why it exists.

DISCUSSION

Form groups of three or four. In your group discuss why TV forensic dramas are not a true reflection of real-life investigations. Think about time frames and entertainment value.

on Resources

eWorkbook Mystery in the house (ewbk-6510)

Weblink How accurate are crime shows on TV?

assesson Additional automatically marked question sets

12.8 Exercise

learnon

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 3	Questions 2, 4	Question 5

Remember and understand

1. Name the examination regularly carried out by both TV investigators and real-life scientists.
2. What is the CSI effect?

Apply and analyse

3. Describe four ways in which TV shows may incorrectly display the accuracy of forensic investigations.
4. A report was filed regarding a hit and run. Outline three pieces of evidence that police may acquire to help identify the car involved.

Evaluate and create

5. Using the information in this subtopic, provide a six-sentence summary outlining the life of a forensic investigator.

Fully worked solutions and sample responses are available on your digital formats.

12.9 Forensics and the future

LEARNING INTENTION

At the end of this subtopic you will be able to describe the possible future of forensic technology and how various breakthroughs are changing the way evidence is obtained and analysed.

12.9.1 Forensic technology

Forensic technology has greatly improved in the last century. Modern science has re-opened old cases and solved mysteries that were hundreds of years old. Technology is still advancing quickly, and scientists are now able to investigate the extremely small world through nanotechnology, access a synchrotron in Victoria, and log onto fingerprint scans and DNA databases that match profiles in record time.

FIGURE 12.45 Forensic technology has come along way in recent years.

12.9.2 Nanotechnology

Nanotechnology is an area of science that is developing across the world. It is the science of extremely small particles — engineering at the atomic and molecular level. Nanotechnology deals with a size scale that is one billionth of a metre. It will enable forensic scientists to analyse the tiniest trace evidence (for example, tiny stains on clothes) for DNA that are still difficult to analyse with current technology.

Nanotechnology will also help scientists develop better tools, such as finer fingerprint powders, so that prints can be revealed on difficult surfaces.

12.9.3 DNA developments

DNA has been one of the biggest breakthroughs in forensic technology in the last three decades. The process of matching DNA profiles is getting faster and less costly, as DNA databases, such as the Australian Government's CrimTrac, continue to expand and connect to each other.

FIGURE 12.46 A larger predatory brown fly feeds on a smaller green fruit fly by puncturing the exoskeleton of the prey and sucking the soft innards out. A DNA analysis of the fly will then show the DNA of itself as well as its prey.

Not only that, DNA profiles can be formed using only minute amounts of DNA. A process known as polymerase chain reaction (PCR), can allow for DNA to be amplified, using as little as a single piece of DNA to make millions of copies in a very short time frame. DNA profiling is no longer being restricted to humans. DNA databases of all main blowflies found in corpses are being developed in Australia, to help entomologists identify maggots and flies faster. The correct identification of flies is crucial to a criminal investigation because each species responds differently to certain environments and temperatures, providing information on what kind of environment a body has been exposed to.

When the DNA of a fly is analysed, it is not just the DNA of the fly that is found. Anything that the fly has ingested is also found. Entomologists are developing techniques in which they can grind up maggots and flies found at a scene, where police suspect a body may once have been, and analyse them for DNA traces, proving whether there was indeed a body or a dead animal present at that scene. Organisms such as maggots, also provide information about when an individual died, which is important to know in forensic investigations.

CASE STUDY: Drugged maggots

In the world of entomology, scientists are developing techniques to examine the presence of drugs in decomposed corpses. Sometimes it is difficult for toxicologists to identify drugs in tissue, but entomologists are looking at ways of analysing maggots found in corpses, for traces of drugs. Maggots consume the drugs in a body when feeding on it and this affects their development. Entomologists are examining these effects to help identify drugged maggots more easily in the future.

FIGURE 12.47 Maggots provide various evidence in forensics investigations.

ACTIVITY: Writing TV crime

Imagine you are a writer for the television show *CSI: Crime Scene Investigation*. You have been asked to write an episode that focuses on the following crime — a robbery at a school. The producers have asked you to draw storyboards (pictures that are drawn to display what a scene will look like) for the five scenes below. Each scene needs to include labels to indicate the major features, such as the evidence. As an extra challenge, add some dialogue between the characters.

a. The crime scene
b. The forensic investigators collecting evidence at the crime scene
c. Forensic scientists analysing the evidence at a laboratory
d. The dramatic arrest of the suspect
e. A newer technology being used to help solve the crime

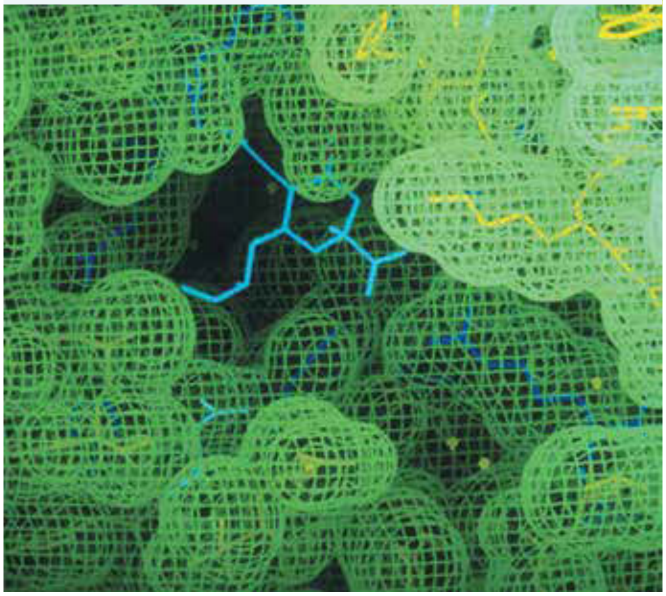
12.9.4 An energy boost: The synchrotron

The **synchrotron** is a machine about the size of a football field. There are very few in the world, and Australia's first synchrotron is in Clayton, Victoria. It works by accelerating electrons to almost the speed of light and deflecting them through magnetic fields so they create extremely bright light. The light is then beamed into experimental workstations, one of which will be a forensic lab.

Typical forensic samples are small and complex substances. Because they are a part of the evidence in a case, they must be kept intact. Scientists are able to analyse all types of substances such as bones, gunshot residue and fibres under the intense light, and gain a better understanding of their components. For example, using synchrotron techniques, scientists can identify forgeries and counterfeit money by analysing the colour pigments, or distinguish car paint pigments involved in hit-and-run accidents. Scientists are also able to develop anti-toxins and gain an understanding of complex molecular structures (figure 12.48).

synchrotron a building-sized device that uses electrons accelerated to near the speed of light to produce intense electromagnetic radiation. This is used to produce data that can describe objects as small as a single molecule.

FIGURE 12.48 Images of complex structures like this helped develop the influenza-fighting drug Relenza™. The synchrotron can also be used to develop anti-toxins.



EXTENSION: The parts of a synchrotron

FIGURE 12.49 The components of a synchrotron

1. **Electron gun:** electrons are fired from a highly-charged tungsten filament.
2. **Linac:** the linear accelerator accelerates the electrons to 99.9987% of the speed of light.
3. **Booster ring:** this increases the energy of the electrons.
4. **Storage ring:** electrons are trapped in circular orbits by large magnets that steer them around. The electrons give off electromagnetic radiation as they change direction; this is synchrotron light.
5. **Beamline:** the beams are focused to a specific wavelength needed for the particular research going on.
6. **Experiment station:** there are many of these positioned around the synchrotron, in which different samples can be analysed by different teams of scientists.

electron gun a part of a synchrotron that allows electrons to be fired from a highly-charged tungsten filament

linac the linear accelerator in a synchrotron that accelerates the electrons to 99.9987% of the speed of light

booster ring a part of a synchrotron that increases the energy of the electrons

storage ring a part of a synchrotron where electrons are trapped in circular orbits by large magnets that steer them around

beamline a part of a synchrotron that directs radiation through a monochromator and into an experimental station

experiment station areas positioned around a synchrotron, in which different samples can be analysed by different teams of scientists

on Resources

Weblinks Nanotechnology and forensics
The Australian Synchrotron

assess on Additional automatically marked question sets

12.9 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

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

Remember and understand

1. MC At which two levels does nanotechnology operate?
   A. Nano and molecular
   B. Micro and nano
   C. Atomic and molecular
   D. Nano and atomic
2. What is the name of the Australian government's DNA database?
3. Which part of a synchrotron produces the electrons?

Apply and analyse

4. What benefits will the synchrotron provide to forensic science?
5. Describe how a national DNA database would assist forensic investigators. Provide three clear examples of this.

Evaluate and create

6. SIS Research other scientific disciplines such as medicine and archaeology. Can you think of other ways the synchrotron might be beneficial to forensic science in the future? Create a report summarising your findings.

Fully worked solutions and sample responses are available on your digital formats.

12.10 Review

Access your topic review eWorkbooks

Topic review level 1	Topic review level 2	Topic review level 3
ewbk-6514	ewbk-6516	ewbk-6518

on Resources

12.10.1 Summary

Who knows who dunnit?

- Two types of forensic investigators exist: police officers who are trained to collect certain types of evidence at a crime scene (for example, fingerprint and ballistics experts, and photographers); and forensic scientists.
- There are many types of forensic scientists, all of whom specialise in different areas. Examples include forensic biologists, chemists, odontologists and psychologists.

Forensic toolbox

- The modern forensic toolbox is sophisticated and complex. Crime laboratories were set up around the world in the 1920s, and this meant a more controlled environment was required when collecting evidence.

Discovering the truth through forensics

- Developments in forensic technology, such as DNA technology, have helped to solve some old mysteries or cold cases, or re-open old cases that were hundreds of years old.

Clues from blood

- Blood left at a crime scene can give scientists and detectives valuable information. Bloodstains can tell an investigator who was at the crime scene and what might have happened. Saliva and dead skin cells can also be traced back to an innocent bystander or a suspect.

Clues in hair, fibres and tracks

- Strands of hair or fibres from clothes, furniture and carpets can provide strong evidence that a suspect has been at a crime scene. Even the most careful criminals can't stop microscopic fibres sticking to their shoes. They may not realise that they have left a single strand of hair behind at a crime scene. Many hairs and fibres look the same, until they are examined under a microscope.

Life as a forensic scientist

- The job of a forensic scientist may also involve coordinating research and innovation.

Forensics and the future

- Technology is still advancing quickly, and soon scientists will be able to investigate the extremely small world through nanotechnology, access a synchrotron in Victoria, and log onto fingerprint scans and DNA databases that match profiles in record time.

12.10.2 Key terms

accelerants a substance that spreads fire easily
anthropologists people who are experts in humans and human remains
arson the criminal act of deliberately setting fire to property
assailant someone who physically attacks another person
beamline a part of a synchrotron that directs radiation through a monochromator and into an experimental station
biased not objective; taking personal experiences and ideologies into account
biologists scientists who study the science of life

booster ring a part of a synchrotron that increases the energy of the electrons
botanists scientists who study the life of plants
chemists scientists who study the atoms and molecules that make up all substances
civil court a court that handles legal disputes, not crimes
coarseness roughness
comparison microscope a microscope that allows two samples to be viewed simultaneously
compensation money that is awarded to someone in recognition of loss or injury
counterfeit an imitation or fake replica of money or a document
cuticle the outer layer of hair
DNA a substance found in all living things that contains genetic information
engineering the field of science and technology that applies scientific principles to design and build structures
electron gun a part of a synchrotron that allows electrons to be fired from a highly-charged tungsten filament
entomologist a person who studies insects
evidence facts or information that can be examined to determine whether a proposition is true
experiment station areas positioned around a synchrotron, in which different samples can be analysed by different teams of scientists
fibres a thread that makes up a material such as a piece of clothing
genetics the study of genes
latent fingerprints fingerprints that are invisible to the human eye
liability an obligation, responsibility, hindrance or something that causes a disadvantage
linac the linear accelerator in a synchrotron that accelerates the electrons to 99.9987% of the speed of light
odontologists scientists who study the structure and diseases of teeth
partial prints a small and incomplete section of a full fingerprint
patent fingerprints fingerprints that leave a visible mark on a surface
pathologists people who study the causes and effects of diseases, examining samples for diagnostic or forensic purposes
psychiatrists psychologists that are also qualified medical doctors
psychology the systematic study of thoughts, feelings and behaviours
speedometer the instrument that displays the speed of a vehicle such as a car or truck
storage ring a part of a synchrotron where electrons are trapped in circular orbits by large magnets that steer them around
suspects people who are thought to be guilty of a crime
synchrotron a building-sized device that uses electrons accelerated to near the speed of light to produce intense electromagnetic radiation. This is used to produce data that can describe objects as small as a single molecule.
ultraviolet light light that is invisible to the human eye but can be used to make certain substances glow

on Resources

eWorkbooks	Study checklist (ewbk-6520) Literacy builder (ewbk-6521) Crossword (ewbk-6523) Word search (ewbk-6525)
Digital document	Key terms glossary (doc-35051)
Practical investigation eLogbook	Forensics Practical investigation eLogbook (elog-0735)

12.10 Exercise

learnON

To answer questions online and receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 4, 5, 8, 14, 15, 20	Questions 3, 6, 9, 11, 12, 16, 17, 21, 23, 26	Questions 7, 10, 13, 18, 19, 22, 24, 25, 27

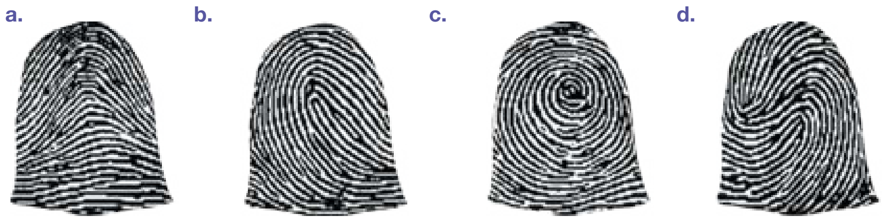
Remember and understand

1. How does a forensic psychiatrist differ from a forensic psychologist?
2. True or false? A polygraph does not provide conclusive evidence of a suspect's guilt or innocence.
3. **a.** Why is a notebook an essential tool for a forensic investigation?
   b. Explain why gloves are required.
   c. What are three possible uses for the putty found in a forensics kit?
   d. Why are tweezers used to collect some types of evidence?
   e. How is fingerprint evidence collected?
4. **MC** DNA evidence would be most useful for:
   A. a forensic chemist
   B. a forensic biologist
   C. a forensic odontologist
   D. a forensic entomologist.
5. **MC** What is orthotolidine used for?
   A. To identify the presence of fibres
   B. To identify the presence of blood
   C. To analyse DNA
   D. To analyse hair follicles
6. **MC** An arc is a blood spatter that forms when:
   A. the attacker pulls a knife out
   B. a knife enters a victim
   C. a victim pulls away from an impact
   D. blood from the victim pools.
7. **MC** Which of the following is **not** an advantage of using a synchrotron for forensic analysis of evidence?
   A. Used primarily for microscope evidence
   B. Evidence remains intact
   C. Provides highly detailed analysis
   D. Can analyse colour pigments
8. The following evidence is collected from a crime scene. Which types of forensic scientist would investigate the:
   a. blood-spattered shoe
   b. bullet shell
   c. toxic liquid
   d. unknown victim
   e. computer?
9. During an investigation, why is it important to interview witnesses to the crime?
10. Why would it be important for a forensic entomologist to know the ambient temperature of the location in which a decomposing body was found?
11. DNA evidence can be used to exonerate a convicted person of a crime. What does this statement mean?

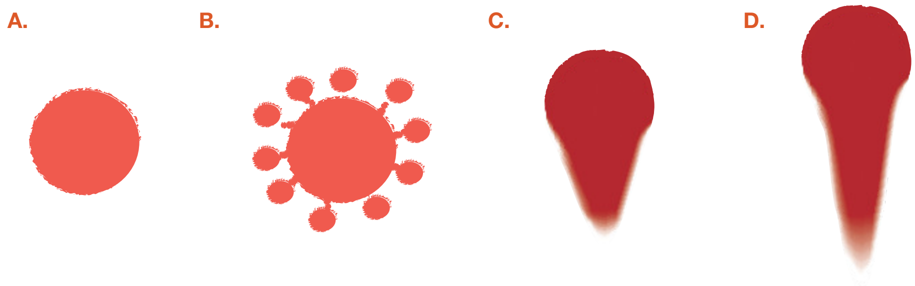
Apply and analyse

12. Bullet exit holes are often larger than the entry holes. Explain why this occurs.
13. If someone said to you, 'It is important for a forensic anthropologist to work closely with a forensic odontologist', would you agree or disagree? Give reasons for your response.

14. It is a dark, murky London night and you are assisting Sherlock Holmes during his investigation of a crime. He has asked you to use the Bertillon method to record a suspect's details.
   a. Name three physical measurements you would record.
   b. Explain why each of the measurements is important.
   c. What are the flaws in using the Bertillon method?
15. Identify the fingerprints below as loop, whorl, arch or composite.



16. Are there any other methods, apart from the polygraph, that could be used to determine whether someone was lying during an investigation? Describe these methods.
17. In the Lindy Chamberlain case, scientific evidence did not initially provide accurate information. Explain why comparing evidence is important in all scientific experiments.
18. If a victim and a suspect were both injured and left type AB blood at a crime scene, how would you determine whose blood was whose?
19. Create a visual summary outlining the details that blood evidence from a crime can provide to forensic investigators. Think about pools of blood, drips of blood, spatters of blood and so on.
20. MC Which of the following blood spatters could be made by a droplet of blood:
   a. falling perpendicularly from a great height
   b. impacting at an angle?

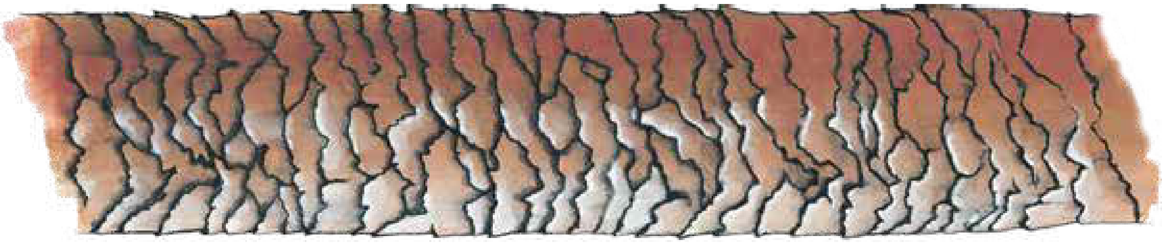


21. Describe an example of the CSI effect.
22. Why has a DNA database been developed for the types of blowflies found in corpses?
23. Crime investigation TV shows may reduce the number of criminals who are caught. Explain why this statement may be correct.

Evaluate and create

24. A criminal found a lost cheque for $10 and decided to write in three extra zeros and the word 'thousand'. He used a blue pen, the same colour as the original writing on the cheque. When he took the cheque to the bank, the teller became suspicious and called the police.
   a. What steps would a forensic scientist use to prove that a different pen had been used to change the cheque?
   b. What other evidence could be obtained to prove that the criminal had written on the cheque?

25. a. Could this fibre in the figure provided be from an animal or from a plant source? Write down the features that would help you decide. List three different possible sources of this fibre that could be found at a crime scene.
    b. What types of further investigation might be necessary to determine the source of the fibre?



26. Some people are worried about the use of DNA databases.
    a. What is a DNA database?
    b. A database could be used to identify criminals more easily in the future. What other applications could the database be used for? (Think beyond investigations of crime.)
    c. Why could the DNA database cause concern among the community? Justify your response.

27. Consider all of the forensic techniques and tools you have looked at during this topic. Choose one tool or technique to research and write a summary to explain how this tool or technique could be improved in the future.

Fully worked solutions and sample responses are available on your digital formats.

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on Resources

eWorkbook Reflection (ewbk-3038)

teachon

Test maker
Create customised assessments from our extensive range of questions, including teacher-quarantined questions. Access the assignments section in learnON to begin creating and assigning assessments to students.

RESOURCE SUMMARY

on Resources

Below is a full list of **rich resources** available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

12.1 Overview

eWorkbooks
- Forensics eWorkbook (ewbk-6494)
- Student learning matrix (ewbk-6527)
- Starter activity (ewbk-6528)

Video eLesson
- How a gun fires bullets in slow motion (eles-4218)

Practical investigation eLogbooks
- Forensics Practical investigation eLogbook (elog-0735)
- Investigation F.1: Recreating a crime scene (elog-0723)

12.2 *The Forensic Herald*

eWorkbook
- How observant are you? (ewbk-6496)

12.3 Who knows who dunnit?

eWorkbook
- Forensic scientists (ewbk-6498)

12.4 Forensic toolkit

eWorkbook
- Forensic toolkits (ewbk-6502)

Video eLesson
- Creating a rolling fingerprint (eles-4219)

Practical investigation eLogbooks
- Investigation F.2: Are you a loop, arch, whorl or composite? (elog-0725)
- Investigation F.3: Exploring UV light (elog-0727)

12.5 Discovering the truth through forensics

eWorkbook
- Using DNA evidence to solve crimes (ewbk-6504)

Video eLesson
- Comparing and matching DNA profiles (eles-4220)

Weblink
- The story of Lindy Chamberlain — 40 years on

12.6 Clues from blood

eWorkbook
- Evidence from blood (ewbk-6506)

Practical investigation eLogbook
- Investigation F.4: Exploring blood splatters (elog-0729)

Weblink
- Australian Police — Bloodstain pattern analysis

12.7 Clues in hair, fibres and tracks

eWorkbooks
- Exploring fibres, hair and tracks (ewbk-6508)
- Read my lips (ewbk-6500)

Practical investigation eLogbooks
- Investigation F.5: Comparing animal and human hair (elog-0731)
- Investigation F.6: Analysing shoe prints (elog-0733)

Weblink
- Different evidence used in forensics

12.8 Life as a forensic scientist

eWorkbook
- Mystery in the house (ewbk-6510)

Weblink
- How accurate are crime shows on TV?

12.9 Forensics and the future

Weblinks
- Nanotechnology and forensics
- The Australian Synchrotron

12.10 Review

Digital document
- Key terms glossary (doc-35051)

eWorkbooks
- Topic review Level 1 (ewbk-6514)
- Topic review Level 2 (ewbk-6516)
- Topic review Level 3 (ewbk-6518)
- Study checklist (ewbk-6520)
- Literacy builder (ewbk-6521)
- Crossword (ewbk-6523)
- Word search (ewbk-6525)
- Reflection (ewbk-3038)

Practical investigation eLogbook
- Forensics Practical investigation eLogbook (elog-0735)

To access these online resources, log on to **www.jacplus.com.au**.

GLOSSARY

abiotic factors the non-living features in an ecosystem
abscisic acid a plant hormone that is involved in the process of development
absolute referencing used in a spreadsheet when a cell address in the formula remains constant, no matter where it is copied to
absolute zero the lowest temperature that is theoretically possible, at which the movement of particles stops. It is zero on the Kelvin scale, equivalent to −273.15 °C.
absorbed energy hitting an object is transferred to it. This will cause the atoms in the object to vibrate more and the temperature will rise.
absorption the taking in of a substance; for example, from the intestine to the surrounding capillaries
abyssal plains relatively flat underwater deep ocean floor, around 4000 metres depth
accommodation changing of the lens shape to focus a sharp image on the retina according to the relative location of the cell that it has been copied to
accurate refers to how close an experimental measurement is to a known value
acetylcholine produced in vesicles in a neuron, this neurotransmitter is released on the arrival of a nervous impulse to travel across the synapse (gap between neurons) to stimulate an impulse in another neuron
acid rain rainwater, snow or fog that contains dissolved chemicals, such as sulfur dioxide, that make it acidic
acids chemicals that react with a base to produce a salt and water; edible acids taste sour
active immunity immunity achieved by your body making antibodies to a specific antigen
active volcano a volcano that is erupting or has recently erupted
adenosine triphosphate (ATP) a form of energy released during cellular respiration that provides cells with the energy needed to perform their functions
adrenal glands a pair of glands situated near the kidneys that release adrenaline and other stress hormones
adrenaline a hormone secreted in response to stressful stimuli, which readies your body for the fight-or-flight response
aerobic respiration the breakdown of glucose to carbon dioxide using oxygen and releasing energy in the form of ATP
alcohol a colourless volatile flammable liquid (such as ethanol, C_2H_5OH) that is made by fermentation of sugars and starches
alkalis bases that dissolve in water
alpha (α) waves waves of electrical impulses emitted by your brain at a frequency of 8–12 Hz associated with being calm, relaxed but aware of your environment
alpha particles positively charged nuclei of helium atoms, consisting of two protons and two neutrons
alternating current current that changes direction along a wire a number of times per second
alveoli tiny air sacs in the lungs at the ends of the narrowest tubes. Oxygen moves from alveoli into the surrounding blood vessels, in exchange for carbon dioxide. Singular = alveolus
ammeter device used to measure the amount of current in a circuit. Ammeters are placed in series with other components in a circuit.
amphetamines nervous system stimulants, such as ‘speed’
amplitude the maximum distance that a particle moves away from its undisturbed position
amygdala emotional centre of the brain, which processes primal feelings such as fear and rage.
amylases enzymes in saliva that break down starch into sugar
anaerobic respiration the breakdown of glucose to simpler substances in the absence of oxygen and release of energy as ATP
analogue quantities that can have any value and change continuously over time
angle of incidence the angle between an incident ray on a surface and the line perpendicular to the surface at the point of incidence, called the normal
angle of reflection the angle measured from the reflected ray to the normal
anther the part of a flower that produces pollen (the male gametes)
antibiotic a substance derived from a micro-organism and used to kill bacteria in the body

antibodies any of various proteins that are produced by B lymphocytes as a result of the presence of a foreign substance in the body and that act to neutralise or remove that substance
anticline a fold in a rock with the narrow point facing upwards
antigen a substance that triggers an immune response
anus the final part of the digestive system, through which faeces are passed as waste
aorta a large artery through which oxygenated blood is pumped at high pressure from the left ventricle of your heart to your body
armature the turning part of an electric motor on which coils of wire are wound
arteries hollow tubes (vessels) with thick walls carrying blood pumped from the heart to other body parts
arterioles vessels that transport oxygenated blood from the arteries to the capillaries
Asian influenza a strain of influenza caused by the H2N2 subtype of influenza virus, which spread across parts of the world in 1956–58
ATP molecule used by cells in chemical reactions that require energy. ATP is a product of cellular respiration.
audio waves with a frequency range of sounds audible to people
auditory nerve a large nerve that sends signals to the brain from the hearing receptors in the cochlea
auricle the fleshy outside part of the ear
autotrophs *see* producer
auxin plant hormone that regulates or modifies the growth of plants such as promoting stem growth, cell expansion and repair
avian influenza a strain of influenza caused by the H5N1 subtype of influenza virus that is highly contagious in birds and has caused over 300 fatalities in humans since 2003
axon long structure within a neuron through which the nervous impulse travels from the dendrite and the cell body
B lymphocyte part of the third line of defence, these lymphocytes may be triggered by antigens to differentiate into plasma cells that produce and release specific antibodies against the antigen; also known as B cells
bacillus a rod-shaped bacterium
barbiturates chemicals that inhibit or decrease synaptic transmission and are hence depressants. They are often taken to calm people down and are used as sedatives.
base station consists of antennas on top of a large tower that transmit signals from mobile phones to a switching centre
bases chemical substances that will react with an acid to produce a salt and water; edible bases taste bitter
beam a wide stream of light rays, all moving in the same direction
beamline part of a synchrotron that directs radiation through a monochromator and into an experimental station
beta (β) waves waves of electrical impulses emitted by your brain at a frequency of 13–30 Hz associated with being strongly engaged and using many of your senses, and perhaps with anxiety
beta particles charged particles (positive or negative) with the same size and mass as electrons
bibliography list of references and sources at the end of a scientific report
biconvex a convex lens with both sides curved outwards
binary code use of the digits 0 and 1 to represent a letter, number, or other character
binaural hearing sound detection in creatures with two ears in order to locate the source of a sound
biologists scientists who study the science of life.
bioaccumulation the magnification of concentrations of a substance such as a nonbiodegradable pesticide along the food chain; also known as **biological magnification**
biodiversity the variety of species of biological organisms, often in relation to a particular area
Black Death *see* bubonic plague
black smoker a geothermal vent on the sea floor that ejects superheated mineral rich water
bladder sac that stores urine
birth rate the number of organisms within a population that are born within a particular period of time
biotic factors the living things (organisms) in an ecosystem
blastocyst a cluster of cells formed in early stages of mammal embryo development, containing an inner cell mass

blog a personal website or web page where an individual can upload documents, diagrams, photos and short videos, add links to other sites and invite other people to post comments
body waves seismic waves that quickly travel through the interior of the Earth
bolus round, chewed-up ball of food made in the mouth that makes swallowing easier
booster ring a part of a synchrotron that increases the energy of the electrons
botanist a scientist who studies plants
brain-control interface technology a direct communication pathway between the brain and an external device
brain stem the part of the brain connected to the spinal cord, responsible for breathing, heartbeat and digestion
bronchi the narrow tubes through which air passes from the trachea to the smaller bronchioles and alveoli in the respiratory system. Singular = bronchus
bronchioles small branching tubes in the lungs leading from the two larger bronchi to the alveoli
brushes part of an electric motor that allows current to travel through the rotor coils by being connected to the power supply and lightly touching the commutator
bubble map a visual thinking tool that organises, analyses and compares by showing common and different features of topics
bubonic plague an infectious, epidemic disease, caused by the *Yersinia pestis* bacteria and carried by fleas from rats; also known as the Black Death
caffeine an excitatory psychoactive drug that stimulates or increases synaptic transmission
capillaries minute tubes carrying blood to body cells. Every cell of the body is supplied with blood through capillaries.
carbon dioxide a colourless gas in which molecules (CO_2) are made up of one carbon and two oxygen atoms; essential for photosynthesis and a waste product of cellular respiration. The burning of fossil fuels also releases carbon dioxide.
carnivores animals that eat other animals
carpel female reproductive organ of a flower, it consists of the stigma, style and ovary
carrier waves are radio waves that are altered in a precise way so that they contain an audio signal
capture, mark, release and recapture a sampling method used to determine the abundance of mobile animals
carrying capacity the maximum population size that a particular environment can sustain
cell body part of a neuron that contains the nucleus
cell the smallest unit of life and the building blocks of living things; also a single battery
cellular immune response immunity involving T lymphocytes (assisted by phagocytes) that actively destroy damaged cells or cells detected as non-self, such as those triggering an immune response
cellular pathogen a pathogen that is made up of cells, such as a tapeworm, fungus or bacterium
cellular phones or mobile phones; so called because base stations that receive mobile phone transmissions are arranged in a network of hexagonal cells
cellular respiration a series of chemical reactions in which the chemical energy in molecules such as glucose is transferred into ATP molecules, which is a form of energy that the cells can use
cellular system a mobile phone system
central nervous system the part of the nervous system composed of the brain and spinal cord
cerebellum the part of the brain that controls balance and muscle action
cerebral cortex the outer, deeply folded surface of the cerebrum
cerebral hemispheres the left and right halves of the brain
cerebrum the largest part of the brain responsible for higher order thinking, controlling speech, conscious thought and voluntary actions
chemical digestion the chemical reactions changing food into simpler substances that are absorbed into the bloodstream for use in other parts of the body
chemical energy energy stored in chemical bonds that is released during chemical reactions
chemical process changes the arrangement of the atoms or molecules of the substances involved
chemical reaction a chemical change in which one or more new chemical substances are produced
chemoreceptors special cells within a sense organ that are sensitive to particular chemicals
chemosynthetic organisms that produce organic material using energy released from chemical reactions rather than light

chips tiny pieces of silicon onto which tiny electric circuits can be etched
chlorophyll the green-coloured chemical in plants that absorbs the light energy so that it can be used in photosynthesis
chloroplast oval-shaped organelle in plants that are involved in the process of photosynthesis, which results in the conversion of light energy into chemical energy
ciliary muscles muscles that control the shape of the lens behind the iris
circadian rhythm the 24-hour pattern of behaviour exhibited in animals and plants even if deprived of environmental changes
circuit breaker safety device that breaks a circuit if the current suddenly exceeds a specified size
circuit diagram diagram using symbols to show the parts of an electric circuit
circulatory system the body system that includes the heart, blood and blood vessels and is responsible for circulating oxygen and nutrients to your body cells and carbon dioxide and other wastes away from them
climate change the alteration of climate patterns on local and global scales. This is not the same as changing weather.
climate cycle any recurring pattern in global or regional climate
clonal selection theory a model for how the immune system responds to infection and how certain types of B and T lymphocytes are selected for destruction of specific antigens invading the body
coaxial cables wires that can transmit a number of different signals as electrical pulses
cocaine an example of an excitatory psychoactive drug that stimulates or increases synaptic transmission
coccus a spherical bacterium
cochlea the snail-shaped part of the inner ear in which receptors are stimulated
cognition another name for thinking or mental activity
collision when two continents crumple together to form a mountain range
colon the part of the large intestine where a food mass passes from the small intestine, and where water and other remaining essential nutrients are absorbed into your body
colour blindness an inherited condition, more common in males, in which a deficiency of one or more of the different types of cones may mean that you find it difficult to see a particular colour or combinations of colours
combustion a chemical reaction when a substance reacts with oxygen and heat is released
commensalism the relationship between organisms where one benefits and the other is unaffected
community more than one population living in the same area at a particular time
commutator device attached to the rotor shaft that receives the current. In most motors it is a metal ring split into sections.
competition the struggle among organisms for food, territory and other factors
components in circuits are the individual electrical devices that are connected in the circuit by conducting wires
compression wave a wave involving the vibration of particles in the same direction as energy transfer
compression a region in which the particles are closer than when not disturbed by a wave; a squeezing force; a squeezing force
computerised axial tomography (CAT) a medical imaging technology employing x-rays to produce a 3D image of a body using computer processing
concave curved inwards
concept map a visual thinking tool that shows the connections between ideas
conducting path connected series of materials along which an electric current can flow
conduction the transfer of heat through collisions between particles
conductors materials that have a very low resistance, allowing current to flow through them with ease
cones photoreceptors located in the retina that respond to red, green or blue light
conservative plate boundary where crust is neither created or destroyed
constipation a condition of the bowels, caused by lack of dietary fibre, in which solid wastes cannot easily leave
constructive plate boundary where new crust is formed
consumer (heterotroph) an organism that relies on other organisms for its food

continental drift movement of the Earth's continents relative to each other over geologic time
continuum a visual thinking tool that shows extremes of an idea or where people stand on a particular idea or issue
control an experimental set-up in which the independent variable is not applied that is used to ensure that the result is due to the variable and nothing else
controlled variables the conditions that must be kept the same throughout an experiment
convection current the movement of particles in a liquid or gas resulting from a temperature of density difference
convection the transfer of heat through the flow of particles
convergent boundary where two tectonic plates move towards each other
converging lens lens that bends rays towards each other. Converging lenses are thicker in the middle than at the edges.
convex curved outwards
core body temperature the operating temperature of an organism, especially near the centre of the body
core hot centre of the Earth made of iron and nickel
cornea the curved, clear outer covering of your eye
corpus callosum a bridge of nerve fibres through which the two cerebral hemispheres communicate
corpus luteum an endocrine structure that is involved in the production of progesterone
corrosive a chemical that wears away the surface of substances, especially metals
cosmic radiation naturally occurring background radiation from outer space
critical angle when the incident angle becomes so great that the incident light can't bend any more
cross-pollination the transfer of pollen from stamens of one flower to the stigma of a flower of another plant of the same type
crude oil liquid formed from the remains of marine plants and animals that died millions of years ago—a fossil fuel. Many other fuel products are obtained from crude oil
crust hard and thin outer rock layer of the Earth
current electricity the flow of electrons through a region
cycle map a visual thinking tool that describes a cyclical process
cytokines signalling molecules that regulate the function between cells of the immune system
cytokinin hormone that promotes cell division in plants
cytosol the fluid found inside cells
death rate the number of organisms within a population that die within a particular period of time
decay to transform into a more stable particle
decibel (dB) a unit of measurement of relative sound intensity
decomposer an organism that breaks down organic matter into inorganic materials
deep ocean trenches narrow and deep troughs in the ocean floor, generally greater than 5000 metres depth
defibrillator a device that delivers a large electric shock to the heart in an attempt to reset its rhythm back to a regular pulse
dehydrated state in which too much water has been lost from the body
delta (δ) waves waves of electrical impulses emitted by your brain at a frequency of 1–3 Hz associated with being in a deep, dreamless sleep
dendrimer a molecule that forms the basic structure of a nanoparticle
dendrite structure that relays information towards the cell body of a neuron
deoxygenated blood blood from which some oxygen has been removed
dependent variable a variable that is expected to change when the independent variable is changed. The dependent variable is observed or measured during the experiment.
depressants inhibitory psychoactive drugs that reduce or decrease synaptic transmission
detritivores animals that feed on and break down dead plants or animal matter
diabetes mellitus a medical condition in which the liver cannot effectively convert glucose to glycogen
diaphragm cone of a loudspeaker that vibrates to produce a sound wave
digestion breakdown of food into a form that can be used by an organism. It includes both mechanical digestion and chemical digestion.

digestive system a complex system of organs and glands that processes food in order to supply your body with the nutrients to cells so they can function effectively
digital quantities that can have only particular values and are represented by numbers
discharged excess charge is removed from an object, either by removing the charged particles, or adding an equal amount of charge of the opposite sign
disease any change that impairs the function of an organism in some way and causes it harm
divergent boundary where two tectonic plates move apart
diverging lens lens that bend rays so that they spread out. Diverging lenses are thinner in the middle than at the edges.
DNA (deoxyribonucleic acid) a substance found in all living things that contains genetic information
dopamine a neurotransmitter involved in producing positive moods and feelings.
dormant volcano a volcano that has erupted in the last 10 000 years but is not currently erupting. They are considered likely to erupt again.
drought resistant being able to store water and hence live for long periods of time without water
drought tolerant being able to tolerate a period of time without water
dry cells devices containing chemicals as solids and pastes that react to supply an electric charge
dynamite relatively stable explosive invented by Alfred Nobel in 1866. It is created by mixing nitroglycerine with an absorbent substance such as silica, forming a paste that can be shaped into rods.
dynamo electric generator
ear canal the tube that leads from the outside of the ear to the eardrum
earth socket connection that provides a route for current to flow to the ground when an electrical appliance malfunctions
earthed excess charge is taken away from the object, by connecting it to the ground
earthquakes a sudden and violent shaking of the ground
echo sound caused by the reflection of sound waves
echolocation the use of sound to locate objects by detecting echoes
ecological niche the role or position of a species or population in its ecosystem in relation to each other
ecology the study of ecosystems
ecosystem communities of organisms that interact with each other and their environment
ectoparasites parasites that live on the outside the body of its host organism
ecstasy an example of an excitatory psychoactive drug; a synthetic hallucinogenic drug (methylenedioxymethamphetamine, MDMA)
ectoparasite parasite that lives outside the body of its host organism
effectors organs that respond to a stimuli to initiate a response
electric charge physical property of matter that causes it to experience a force when near other electrically charged matter. Electric charge can be positive or negative.
electric current a measure of the number of electrons flowing through a circuit every second
electric generator device that transforms kinetic energy of rotation into electrical energy
electric motor device that converts electrical energy into kinetic energy of a rotating shaft
electrical conductors materials through which electricity flows easily
electrical insulators materials which do not allow electricity to flow easily
electrodes conductor through which an electric current enters or leaves a cell
electroencephalogram (EEG) a device that detects and records the electrical activity of the brain
electrolyte acid, base or salt that conducts electricity when dissolved in water or melted
electromagnet magnet formed by wrapping a coil of wire around an iron core. When electricity passes through the coil, the iron core becomes an electromagnet.
electromagnetic pulse a burst of electromagnetic activity caused by the detonation of nuclear devices
electromagnetic waves electromagnetic energy that is transmitted as moving electric and magnetic fields. There are many different types of electromagnetic energy; for example, light, microwaves, radio waves.
electron gun a part of a synchrotron that allows electrons to be fired from a highly-charged tungsten filament
electrons extremely light (1800 times lighter than protons and neutrons) negatively charged particles inside an atom. Electrons orbit the nucleus of an atom.

embryonic stem cells stem cells derived from the inner cell mass of a blastocyst. These cells are pluripotent and can give rise to most cell types.
emigration the number of individuals leaving an area
empathy the capacity to recognise and to some extent share feelings that are being experienced by other people
endocrine glands organs that produce hormones, which are released into the bloodstream
endocrine system the body system composed of different glands that secrete signalling molecules (hormones) that travel in the blood for internal communication and regulation and to maintain homeostasis
endoparasite parasite that lives inside the body of its host organism
endorphins hormones resembling opiates that are released by the brain when you are in pain, in danger or under other forms of stress
endoscope a long, flexible tube with one optical fibre to carry light to an area inside the body and another optical fibre to carry light from the body to a lens. The image formed by the lens is examined or recorded.
endothermic chemical reactions that absorb heat energy from the surroundings
enhanced greenhouse effect the additional heating of the atmosphere due to the presence of increased amounts of carbon dioxide, methane and other gases produced by human activity
energy pyramid a representation of the level of food energy at each level within a food chain
enzymes special chemicals that speed up reactions but are themselves not used up in the reaction
epicentre the surface point directly above the earthquake focus
epidemic a disease affecting a large number of people in a particular area in a relatively short period of time
erythrocytes red blood cells
ephemeral describes lasting for only a very short time
ethanol an end product of anaerobic respiration in plants
ethics the system of moral principles on the basis of which people, communities and nations make decisions about what is right or wrong
ethylene gaseous plant hormone involved in the ripening of fruits and the lowering and dropping (abscission) of leaves
eutrophication a form of water pollution involving an excess of nutrients such as nitrates and phosphorus, resulting in algal blooms and possible death of fish and other organisms
evaporation the change of a liquid into a vapour at a temperature below the boiling point and at the surface of a liquid. Molecules with the highest kinetic energy escape, lowering the temperature of the liquid.
excitatory psychoactive drugs chemicals such as caffeine that increase or stimulate synaptic transmission
excretory system the body system that removes waste substances from the body
exothermic chemical reactions that give out heat energy to the surroundings
experiment station areas positioned around a synchrotron, in which different samples can be analysed by different teams of scientists
exponential growth a rapid increase in number or size, represented by a J-shaped graph
external radiotherapy cancer treatment where radiation is directed from an external machine to the site of the cancer
extinct volcano a volcano that has not erupted in the last 10 000 years. They are considered dead and not to erupt again.
fair testing a method for determining an answer to a problem without favouring any particular outcome; another name for a controlled experiment
fats organic substances that are solid at room temperature and are made up of carbon, hydrogen and oxygen atoms
fault a break in the crust where one side moves relative to the other
fertilisation fusion of the male sex cell (sperm) and the female sex cell (ovum); in plants it involves the fusion of the pollen grain and egg cell
fibrillation rapid twitching of the heart muscle, which disrupts its rhythm; can cause heart attacks
field magnets magnets producing a magnetic field that acts on the rotor coils
fields regions around an object in which each point is affected by a force of some type
filament coil of wire made from a metal that glows brightly when it gets hot

first-order consumer an organism that is within the second trophic level of a food chain (herbivores); also known as a primary consumer
fishbone diagram a visual thinking tool that analyses and compares by breaking an event into smaller causes to show why something has happened
flaccid limp, not firm
fission splitting of the nuclei of large atoms into two smaller atoms and several neutrons, releasing radiation and heat energy
focal point the focus for a beam of light rays
focus the location underground of the fault movement causing an earthquake
folding when rocks bend into anticlines or synclines
follicle-stimulating hormone (FSH) regulates the development, growth and reproductive processes of the body
follicles found in the ovary and contain a single immature ovum (egg)
forebrain consists of the cerebrum, cerebral cortex, thalamus and hypothalamus
flow chart a visual thinking tool that shows a sequence of events or steps in a process
flower the structure in flowering plants (angiosperms) that contains reproductive organs
food chains a flow chart that shows the flow of energy from one organism to another as a result of feeding relationships
food webs diagram that shows interlocking food chains within an ecosystem
fossil fuels substances, such as coal, oil and natural gas, that have formed from the remains of ancient organisms; they can be burned to produce heat
fossils the remains, impression or trace of a living organism preserved in rock
frequency the number of vibrations in one second, or the number of wavelengths passing in one second
fuel rods one of the rods that form the fuel source of a nuclear reactor; contains the fissile nuclides needed to produce a nuclear chain reaction
fuel a substance that is burned in order to release energy, usually in the form of heat
fumigants chemicals used in the form of smoke or fumes, to kill pests
functional magnetic resonance imaging (fMRI) a type of specialised MRI scan used to measure the change in blood flow related to neural activity in the brain or spinal cord
functional magnetic resonance spectroscopy (fMRS) a medical imaging technique used to measure levels of different metabolites in body tissues
functions common type of calculation built into spreadsheets
fungi organisms, such as mushrooms and moulds — some help to decompose dead or decaying matter and some cause disease
fungicides chemicals used to kill fungal growth
fuse safety wire that melts when too much current flows through it. Fuse wires are designed to melt at different currents.
gall bladder a small organ that stores and concentrates bile within the body
galvanometer an instrument used to measure small electric currents; named after Luigi Galvani
gamma rays high-energy electromagnetic radiation produced from some radioactive decay; the radiation has no mass and travels at the speed of light
genetic modification (GM) the technique of modifying the genetic structure of organisms making it possible to design organisms that have certain characteristics
geostationary orbit describes the path of a satellite that remains above the same location of the Earth's surface
GHB gamma hydroxybuturate, also known as liquid E or fantasy, which depresses the nervous system
gibberellin plant hormone that regulates growth, including germination and dormancy
gametes sex cells
glucagon a hormone, produced by the pancreas, which increases blood glucose levels
glucose a six-carbon sugar (monosaccharide) that acts as a primary energy supply for many organisms
glycaemic index (GI) a measure of how quickly a particular food raises the level of blood sugar over a two-hour period
glycogen the main storage carbohydrate in animals, converted from glucose by the liver and stored in the liver and muscle tissue

glycolysis the process (that does not require oxygen) in which glucose is broken down into simpler molecules and energy is released in the form of ATP

Gondwana the southern part of the broken-up supercontinent of Pangaea, which included the continents of Africa, South America, Antarctica and Australia; also known as Gondwanaland

greenhouse effect the heating of the atmosphere due to the presence of carbon dioxide, methane and other gases

ground zero the centre of a nuclear weapon blast

guard cells cells surrounding each stoma in a leaf enabling it to open or close depending on the availability of water

gut flora bacteria and other organisms that live inside the intestines and help digest food

habitat where a species lives within the ecosystem

haemoglobin the red pigment in red blood cells that carries oxygen

half-life time taken for half the radioactive atoms in a sample to decay — that is, change into atoms of a different element

heart a muscular organ that pumps blood through the circulatory system so that oxygen and nutrients can be transported to the body's cells and wastes can be transported away

heat sink device that transfers the heat generated by an electronic or a mechanical component to a coolant, often the air or a liquid, where it can be taken away from the component

herbicides chemicals used to kill unwanted plants (weeds)

herbivores animals that eat only plants

heroin an inhibitory psychoactive drug that decreases synaptic transmission

higher-order thinking involves problem solving and decision making

hindbrain a continuation of the spinal cord

hippocampus part of the brain with a key role in consolidating learning, comparing new information with previous experience, and converting information from working memory to long-term storage

Hippocratic Oath an oath historically taken by doctors that requires them to follow ethical rules and principles

homeostasis the maintenance by an organism of a constant internal environment (for example, blood glucose level, pH, body temperature)

hormones a signalling molecule that is produced in specialised cells and travels in blood to act on target cells to cause a specific response

horst a highland between two normal faults

host organism living in a relationship with another organism

hotspot a volcanic region directly above an area of anomalously hot mantle

humoral immune response immunity involving antibodies (which are specific to a particular antigen) that are produced and secreted by B lymphocytes that have differentiated into plasma cells

hydrocarbons compounds containing only hydrogen and carbon atoms

hypothalamus a part of the forebrain that monitors internal systems and coordinates the nervous and endocrine systems to maintain homeostasis

hypothermia a dangerous medical condition that occurs when the body temperature is below its normal range

immigration the number of individuals moving into an area

immune system a network of interacting body systems that protects against disease by identifying and destroying pathogens and infected, malignant or broken-down cells

immunisation administering an antigen, such as in a vaccine, with the aim of producing enhanced immune response against the antigen in a future exposure

immunity resistance to a particular disease-causing pathogen

immunology the branch of science that deals with immunity from disease

implanted electrodes technological devices that have a number of medical applications, such as their direct connection to a human brain, with the aim of providing assistance to people with a variety of disabilities

incident ray the ray that approaches the mirror

independent variable a variable that is deliberately changed during an experiment

indicator a substance that changes colour when it reacts with acids or bases; the colour shows how acidic or basic a substance is

induction a process where the electrical or magnetic properties of an object produces similar properties in a nearby object without physical contact; for example, the production of a current by repeatedly moving a magnet in and out of a coil

infectious disease a disease that is contagious (can be spread from one organism to another) and caused by a pathogen

inflammation a reaction of the body to an infection, commonly characterised by heat, redness, swelling and pain

infra-red radiation invisible radiation emitted by all warm objects. You feel infra-red radiation as heat.

inhibitory psychoactive drugs chemicals, such as barbiturates, that decrease synaptic transmission

inner core solid inner-most layer of the core under extreme pressure conditions, with an approximate 1200 km radius

insecticides chemicals used to kill insects

insect pollination the transfer of pollen from one flower to another by insects

insulator material that has a very high resistance, allowing very little current to flow through it

insulin hormone that removes glucose from the blood and stores it as glycogen in the liver and muscles

integrated circuits electric circuits made up of miniature components that can be etched onto silicon chips

intermediate host the organism that a parasite lives in or on in its larval stage; also known as secondary host

internal radiotherapy cancer treatment also known as brachytherapy. Radioisotopes are placed inside the body at, or near, the site of a cancer.

interneuron a nerve cell that conducts a nerve impulse within the central nervous system, providing a link between sensory and motor neurons

interspecific competition competition between organisms of the different species

intraspecific competition competition between organisms of the same species

iris coloured part of the eye that opens and closes the pupil to control the amount of light that enters the eye

introduced species an organism that has been released into an ecosystem in which it does not occur naturally

isotopes atoms of the same element that differ in the number of neutrons in the nucleus

kerosene fuel used in jet aircraft

kidneys body organs that filter the blood, removing urea and other wastes

kinetic energy energy due to the motion of an object

lactic acid an end product of anaerobic respiration in animals; also known as lactate

lactate *see* lactic acid

large intestine the penultimate part of the digestive system, where water is absorbed from the waste before it is transported out of the body

lateral inversion reversed sideways

Laurasia the northern part of the broken-up supercontinent of Pangaea, which included the continents of North America, Europe and Asia

lava extremely hot liquid or semi-liquid rock from the mantle, which has reached and flows or erupts on the Earth's surface

Law of Conservation of Mass in a chemical reaction, the total mass of the reactants is the same as the total mass of the products

Law of Constant Proportions in chemical compounds, the ratio of the elements is always the same

Law of Reflection the angle of incidence must equal the angle of reflection

left atrium upper left section of the heart where oxygenated blood from the lungs enters the heart

left ventricle lower left section of the heart, which pumps oxygenated blood to all parts of the body

lens a transparent, curved object that bends light towards or away from a point called the focus. The eye has a jelly-like lens.

liability an obligation, responsibility, hindrance or something that causes a disadvantage

light-emitting diodes a device that emits visible light when a current, which flows in one direction only, passes through it

light energy sunlight energy or energy from an artificial light source

limbic system a collection of structures within your brain involved in memory, controlling emotions, decision making, motivation and learning

linac the linear accelerator in a synchrotron that accelerates the electrons to 99.9987% of the speed of light
linear accelerator the part of a synchrotron that uses extremely high voltages (100 million volts) to accelerate electrons to 99.9987 per cent of the speed of light
lipases enzymes that break fats and oils down into fatty acids and glycerol
liver largest gland in the body. The liver secretes bile for digestion of fats, builds proteins from amino acids, breaks down many substances harmful to the body and has many other essential functions.
load device that uses electrical energy and converts it into other forms of energy
logbook a complete record of an investigation from the time a search for a topic is started
longitudinal wave *see* compression wave
long-sightedness (hyperopia) the condition of not being able to see clearly things that are close
Love waves a surface seismic wave with a side-to-side motion
luminous object that releases its own light
lungs the organ for breathing air. Gas exchange occurs in the lungs.
luteinising hormone (LH) hormone produced by the anterior pituitary gland that initiates ovulation, the production of progesterone and corpus luteum development in females and in the stimulation of production of testosterone in testes in males
lymphatic system the body system containing the lymph vessels, lymph nodes, lymph and white blood cells that is involved in draining fluid from the tissues and helping defend the body against invasion by disease-causing agents
lymphocyte small, mononuclear white blood cells present in large numbers in lymphoid tissues and circulating in blood and lymph
lysozyme a chemical (enzyme) in human teardrops able to kill some types of bacteria as part of your body's natural defence
magma extremely hot liquid or semi-liquid rock within the mantle. When it erupts on the surface of the Earth it is called lava.
magnetic field area where a magnetic force is experienced by another magnet. The direction of the magnetic force is shown by drawing field lines; the size of the force is shown by how close together the lines are.
magnetic resonance imaging (MRI) a medical imaging technique employing a powerful magnetic field and radio waves to produce a 3D image of a body
magnetoencephalography (MEG) a medical imaging technique for mapping brain activity by recording magnetic fields produced by electrical currents occurring naturally in the brain
main switch control switch that turns all the household circuits on or off
mantle solid but soft middle rock layer of the Earth
marijuana plant in which the active ingredient is an inhibitory psychoactive drug that reduces or decreases synaptic transmission; sometimes called cannabis
matrix a visual thinking tool that organises, analyses and compares using a grid
mechanical digestion digestion that uses physical factors such as chewing with the teeth
mechanical waves waves carried by the vibration of particles of matter
mechanoreceptors special cells within the skin, inner ear and skeletal muscles that are sensitive to touch, pressure and motion
medium a material through which a wave moves
medulla oblongata (medulla) a part of the brain developed from the posterior portion of the hindbrain
melatonin hormone produced by the pineal gland that is involved in sleepiness
meltdown the melting of a nuclear-reactor core as a result of a serious nuclear accident
membrane a thin layer of tissue
memory cells cells that may be formed from lymphocytes after infection with a pathogen — they 'remember' each specific pathogen encountered and are able to mount a strong and rapid response if that pathogen is detected again
menstruation monthly discharge of blood and other materials from the uterus lining through the vagina (also known as period)
metabolism the chemical reactions occurring within an organism to maintain life
methane the smallest hydrocarbon (CH_4), it is the main component of natural gas

microbiome the community of microorganisms (such as bacteria, fungi, and viruses) living together in a particular habitat
micrometre one millionth of a metre
microprocessor electronic central processing units of computers on a microchip
microwave an electromagnetic wave of very high frequency
middle ear the section of the ear between your eardrum and the inner ear, containing the ossicles
mind map a visual thinking tool with a central idea and associated ideas arranged around it
minerals any of the inorganic elements that are essential to the functioning of the human body and are obtained from foods
mirror neurons group of neurons that activate when you perform an action and when you see or hear others performing the same action
mitochondrion a small rod-shaped organelle that supplies energy to other parts of the cell
model simplified description, often a mathematical one, of a process
monochromator a material that allows only specific wavelengths of radiation to pass through
motor neuron disease a medical condition that progressively destroys motor neurons, resulting in progressive paralysis but leaving the brain and sense organs unaffected
motor neuron a nerve cell that conducts a nerve impulse from the central nervous system to the effector, such as a muscle or gland so that it may respond to a stimulus
moulds types of microscopic fungi found growing on the surface of foods
multicellular organism a living thing that is made up of many cells
mountain range a group of high ground features, commonly the result of tectonic collision
multipotent stem cells that can differentiate into only a few cell types
mutation damage to DNA in cells, which can be passed on to children through sperm and eggs
mutualism the relationship between two different organisms in which both benefit
myelin a fatty, white substance that encases the axons of neurons
myelination the process of neurons becoming coated in a myelin sheath
myopia *see* short sighted
nanometre one billionth of a metre
nanoparticle a microscopic particle about 0.1–100 nanometres in size
natural gas formed from the remains of plants and animals that died millions of years ago; it is a fossil fuel
negative feedback a homeostatic mechanism that returns a stimulus back within its normal range
negatively charged having more electrons than protons (more negative charges than positive charges)
nephrons the filtration and excretory units of the kidney
nerve a bundle of neurons
nervous system the body system in which messages are sent as electrical impulses (along neurons) and chemical signals (neurotransmitters across synapses)
neural prostheses technological devices that can replace a motor, sensory or cognitive structure
neurogenesis the creation of neurons
neuron another name for nerve cell, a specialised cell for transmitting a nerve impulse
neurotoxic leads to the death of neurons
neurotransmitters signalling molecules released from the axon terminals into the synapse between nerve cells (neurons)
neutralisation a reaction between an acid and a base. A salt and water (a neutral liquid) are the products of this type of reaction
neutrons tiny particles found in the nucleus of an atom. Neutrons have no electrical charge and the same mass as a proton.
nocturnal being active only at night
non-cellular pathogen a pathogen that is not made up of cells, such as a virus, prion or viroid
non-infectious disease a disease that cannot be spread from one organism to another
non-luminous objects that release no visible light of their own
noradrenaline also called norepinephrine; common neurotransmitter involved in arousal states
normal fault a break where the rock above the fault moves ‘down’ due to tension

normal is a line drawn perpendicular to a surface at the point where a light ray meets it
north pole end of the magnet that when free to rotate, points to the north pole of the Earth
nuclear fallout irradiated dust blasted high into the atmosphere during detonation and the formation of the mushroom cloud. In the weeks following the nuclear explosion, these come back down to Earth as nuclear fallout.
nuclear radiation radiation from the nucleus of an atom, consisting of alpha or beta particles, or gamma rays
nuclear reactors power plants where the radioactive properties of uranium are used to generate electricity
nucleus central part of an atom, made up of protons and neutrons; plural = nuclei
nuclide a type of atom characterised by the number of protons and the number of neutrons in its nucleus
obligate anaerobes organisms that can respire only anaerobically (in the absence of oxygen)
obligate intracellular parasite a parasite that needs to infect a host cell before it can reproduce
ocean ridges submarine mountains that tower 2000 metres above the abyssal plains
octane a hydrocarbon with eight carbon atoms, it is the major component of petrol (C_8H_{18})
oesophagus part of the digestive system composed of a tube connecting the mouth and pharynx with the stomach
oestrogen hormone secreted from the ovaries and the placenta with a variety of effects such as inducing puberty changes and thickening of the uterus lining
Ohm's Law states that the current in a conductor is proportional to the voltage drop across the conductor
ohmic describes conductors that obey Ohm's Law
olfactory nerve nerve that sends signals to the brain from the chemoreceptors in the nose
omnivores animals that eat plants and other animals
opaque a substance that does not allow any light to pass through it
opiates drugs derived from the opium poppy that involve the neurotransmitter dopamine in stimulating pleasure centres in the brain; they may also induce sleep and alleviate pain
optic nerve large nerve that sends signals to the brain from the sight receptors in the retina
optical fibres narrow strands made of two concentric glass layers so that the light is internally reflected along the fibres
optimum range the range, within a tolerance range for a particular abiotic factor, in which an organism (of a particular species) functions best
organelle a structure in a cell with a particular function
ossicles a set of three tiny bones that send vibrations from the eardrum to the inner ear
outer core liquid outer layer of the core, about 2300 km thick
oval window an egg-shaped hole covered with a thin tissue. It is the entrance from the middle ear to the outer ear.
ovary in flowering plants, is the hollow, lower end of the carpel containing the ovules (the female egg cells)
ovulation the release of an ovum
ovum female sex cells produced in the ovaries
oxidation a chemical reaction involving the loss of electrons by a substance
oxygen tasteless and colourless gas in which molecules (0_2) are made up of two oxygen atoms. It is essential for cellular respiration for most organisms and is a product of photosynthesis.
oxytocin a hormone that induces labour and milk release from mammary glands in females
P-waves or primary waves body seismic waves with a compressional (push-and-pull) motion; are the fastest and first to arrive
pain receptors special cells located throughout the body (except the brain) that send nerve signals to the brain and spinal cord in the presence of damaged or potentially damaged cells
pancreas a large gland in the body that produces and secretes the hormone insulin
pandemic a disease occurring throughout an entire country or continent, or worldwide
Pangaea a supercontinent that existed about 225 million years ago. All landmasses were joined together to form this supercontinent.
Panthalassa the vast ocean surrounding the supercontinent of Pangaea
papilla bumps on your tongue that are thought to contain tastebuds
parallax error error caused by reading a scale at an angle rather than placing it directly in front of the eye

parallel circuit a circuit that has more than one path for electricity to flow through. If one of the paths has a break in it, the others will still work.
paralysis loss of the ability to move
parasite organism that obtains resources from another organism (host) that it lives in or on, and can cause harm to
parasitism an interaction in which one species (the parasite) lives in or on another species (the host) from which it obtains food, shelter and other requirements
passive immunity immunity achieved by your body receiving antibodies from an outside source, such as from your mother's milk or through vaccination
pathogen a disease-producing organism
penicillin a powerful antibiotic substance found in moulds of the genus *Penicillium* that kills many disease-causing bacteria
perennial means lasting for three or more years
peripheral nervous system the part of the nervous system containing nerves that connect to the central nervous system
peristalsis the process of pushing food along the oesophagus or small intestine by the action of muscles
permanent magnets magnets that retain their magnetic effect for many years
perspiration the salty fluid produced by sweat glands under the skin
pH scale the scale from 1 (acidic) to 14 (basic) that measures how acidic or basic a substance is
phage a type of virus that infects and kills bacteria
phagocyte white blood cell that ingests and destroys foreign particles, bacteria and other cells
phagocytosis the ingestion of solid particles by a cell
phloem vascular tissue that transports organic substances (for example, sugars) within plants
photon a particle such as a quantum of light or electromagnetism
photoreceptor a special cell located in your eye that is stimulated by light
photosynthesis a series of chemical reactions in the chloroplasts of plant cells that uses light energy, carbon dioxide and water to produce oxygen, water and sugars (food)
pickling preserving food by storing it in vinegar (ethanoic acid)
pie chart a diagram using sectors of a circle to compare the sizes of parts making up a whole quantity
pineal gland gland that produces the hormone melatonin, which can make you feel drowsy
pistil the female reproductive organ of a flower that consists of one or more carpel (made up of the stigma, style and ovary)
pitch how our hearing interprets frequency. High frequency vibrations are perceived as high pitch, low frequency waves are perceived as low pitch.
pituitary gland a small gland at the base of the brain that releases hormones
plagues contagious diseases that spread rapidly through a population and results in high mortality (death rates)
plasma cell *see* B lymphocyte
plate tectonics a scientific theory that describes the relative movements and interaction of plates of the Earth's crust over the underlying mantle
plateau phase a state in which conditions are balanced and there is neither growth nor a decrease in number; also known as steady state or equilibrium
pluripotent stem cells that can differentiate into most cell types; for example, blood cells, skin cells and liver cells
PMI chart visual thinking tool that classifies using positive, negative and interesting features
poliomyelitis a highly infectious disease caused by the *Picornaviridae* virus that can have consequences including complete recovery, limb and chest muscle paralysis, or death
pollination the transfer of pollen from the stamen (the male part) of a flower to the stigma (the female part) of a flower
pollinators transfer pollen from one flower to another
pons part of the brain involved in regulating sleep, arousal and breathing, and coordinating some muscle movements
pollen grains the male gametes of a flower

population density the number of a species living within an area
population distribution the area inhabited by a plant or animal species
positive feedback a homeostatic mechanism that enhances the original stimulus
population distribution the area inhabited by a plant or animal species
population a group of individuals of the same species living in the same area at a particular time
positively charged having more protons than electrons (more positive charges than negative charges)
positron emission tomography (PET) a nuclear medicine imaging technique employing gamma rays to produce a 3D image of a body or functional processes in the body
positron a particle emitted during PET, which is like an electron but with a positive charge
potential difference also known as voltage, is the change in the amount of energy stored in electrons as they move through a component or a circuit
power supply a device that can provide an electric current
precise refers to how close multiple measurements of the same investigation are to each other
predator–prey relationships a relationship between organisms in which one species (the predator) kills and eats another species (the prey)
primacy remembering the first time that you do something, or the beginning of something
primary consumers the first consumers in a food chain; also known as a first-order consumers
primary host the organism that a parasite lives in or on in its adult stage
prion an abnormal and infectious protein that converts normal proteins into prion proteins
priority grid a visual thinking tool that quantifies and ranks based on two criteria
products chemical substances that result from a chemical reaction
progesterone hormone produced in the ovaries that inhibits ovulation and prepares the lining of the uterus for pregnancy
proteases enzymes in saliva that break down starch into sugar
protons tiny particles found in the nucleus of an atom. Protons have a positive electrical charge and the same mass as a neutron
pseudoscience an apparently scientific approach to a theory that on close analysis is shown to have no scientific validity
psychoactive drugs chemicals that decrease synaptic transmission (such as barbiturates) or increase synaptic transmission (such as caffeine)
pulmonary artery the vessel through which deoxygenated blood, carrying wastes from respiration, travels from the heart to the lungs
pulmonary vein the vessel through which oxygenated blood travels from your lungs to the heart
pupil a hole through which light enters the eye
pyramid of biomass a representation of the dry mass of organisms at each level within a food chain
pyramid of numbers a representation of the population, or numbers of organisms, at each level within a food chain
quadrats a sample method used to estimate the distribution and abundance of organisms that are stationary or nearly stationary. The sampling area is typically 1 square metre.
qualitative data (or categorical data) data expressed in words
quantitative data (or numerical data) data that can be precisely measured and have values that are expressed in numbers
quarantine strict isolation of sick people from others for a period of time (originally 40 days) in order to prevent the spread of disease
radiant heat heat that is transferred from one place to another by radiation
radiation sickness immediate symptoms of exposure to damaging nuclear radiation
radiation a method of heat transfer that does not require particles to transfer heat from one place to another
radio waves low-energy electromagnetic waves with a much lower frequency and longer wavelength than visible light
radioactive describes atoms that are unstable and emit a particle to remove excess energy. These particles are capable of ionising other atoms upon collision, which can cause harm to living tissue.

radiocarbon dating a method of determining the age of a fossil using the remaining amount of unchanged radioactive carbon

radioisotope a radioactive form of an isotope

radiometric dating determining the ages of rocks and fossils based on the rate of decay or half-life of particular isotopes

random errors an error that occurs due to estimation when reading scales, or when the quantity being measured changes randomly

rarefaction a region in which the particles are further apart than when not disturbed by a wave

Rayleigh waves a surface seismic wave that has a rolling motion

rays narrow beams of light

reactants the original substances present in a chemical reaction

receiving antenna a metal structure in which electrons are made to vibrate by radio waves or microwaves in the atmosphere

recency remembering the last time that you do something, or the end of something

receptors special cells that detect energy and convert it to electrical energy that is sent to the brain cellular respiration a series of chemical reactions in which the chemical energy in molecules such as glucose is transferred into ATP molecules, which is a form of energy that the cells can use

rectifier device that changes alternating current to direct current

rectum the final section of the digestive system, where waste food matter is stored as faeces before being excreted through the anus

red blood cells living cells in the blood that transport oxygen to all other living cells in the body. Oxygen is carried by the red pigment haemoglobin.

reflected ray the ray that leaves the surface of the mirror

reflection bouncing off the surface of a substance

reflex arc a quick response to a stimulus that does not involve the brain (for example, knee jerk). The message travels from receptor to sensory neuron to interneuron in the spinal cord then directly via the motor neuron to the effector.

relative referencing used in a spreadsheet when the cell address in the formula is changed

relative sound intensity a measure of the energy of a sound, which provides an indication of loudness. It is measured in decibels (dB) and is often referred to as sound level.

reliable data data that is able to be replicated in different circumstances but the same conditions

repeater station retransmits communication signals with increased energy so the signal does not fade away.

residual current devices a form of safety switch that can quickly detect a possible fault and break the flow of electricity in a circuit in order to prevent electrocution

resistance measure of the electrical energy required for an electric current to pass through an object, measured in ohms (Ω)

resistors circuit component that has resistance

respiration the process by which your body gains energy by breaking down glucose, using oxygen and creating carbon dioxide and water; a slow combustion reaction

respiratory system the body system that includes the lungs and associated structures and is responsible for the gas exchange of getting oxygen into your body and carbon dioxide out

reticular formation a network of neurons that controls the amount of information that flows into and out of the brain

retina curved surface at the back of the eye

reverse fault a break where the rock above the fault moves 'up' due to compression

Richter scale a logarithmic scale that measures the amount of energy released during an earthquake, thus allowing one earthquake to easily be compared to another

rift valleys a sunken lowland between two normal faults; a graben

right atrium upper right section of the heart where deoxygenated blood from the body enters

right ventricle lower right section of the heart, which pumps deoxygenated blood to the lungs

RNA (ribonucleic acid) complex compound that functions in cellular protein synthesis and replaces DNA as a carrier of genetic codes

rods photoreceptors located in the retina that respond to low levels of light and allow you to see in black and white in dim light

rotor coils coils of a motor that turn when a current flows through them

S-waves or secondary waves body seismic waves with a transverse (up-and-down) motion; are slower than P-waves and cannot travel through fluids

saliva watery substance in the mouth that moistens food before swallowing and contains enzymes involved in the digestion of food

salivary glands glands in the mouth that produce saliva

sampled in the context of music, means to measure the amplitude at regular intervals in order to convert a sound into a string of numbers for digital transmission

sampling methods techniques used to determine the density and distribution of various populations and communities within an ecosystem

satellite an object that orbits another object. The moon is the Earth's satellite. Scientists have made and launched many artificial satellites.

scattering light sent in many directions by small particles within a substance

scientific method a systematic and logical process of investigation to test hypotheses and answer questions based on data or experimental observations

sea breeze the breeze that occurs when differences in air pressure cause air particles to flow from the ocean towards the land

sea-floor spreading the formation of oceanic crust, which occurs by the rising and melting mantle at ocean ridges that push older crust away from the ridge

second-order consumer an organism that is within the third trophic level of a food chain (carnivores); also known as a secondary consumer

seismic waves waves released when rock breaks or is rapidly moved

seismograph an instrument used to detect and measure the intensity of an earthquake

seismologist a scientist who studies earthquakes to both understand how they work and how to better predict them

self-pollination the transfer of pollen from the flower's own stamen to its stigma

semicircular canals three curved tubes, filled with fluid, in the inner ear that control your sense of balance

sense organ a specialised structure that detects stimuli (such as light, sound, touch, taste and smell) in your environment

sensory neuron a nerve cell in the sensory organs that conducts a nerve impulse from receptors to the central nervous system

sensory register part of the information processing model of the brain that involves filtering incoming information

series circuit a circuit with the components joined one after the other in a single continuous loop

series a formation of electricity-generating or using devices whereby the electricity passes from one device to the next in a single conducting loop, one after the other

serotonin a common neurotransmitter involved in producing states of relaxation and regulating sleep and moods

shaft central rotating rod of the motor that transmits the kinetic energy

shearing a smearing force

short sighted (myopia) the condition of not being able to see things clearly that are far away

short-sightedness (myopia) the condition of not being able to see clearly things that are far away

sigmoid the shape of a graph that shows a population increasing in number then reaching a plateau

skin external covering of an animal body

small intestine the part of the digestive system between the stomach and large intestine, where much of the digestion of food and absorption of nutrients takes place

solenoid coil of wire able to pass a current

somatic stem cells undifferentiated multipotent cells that are found in adults and umbilical cord blood; they can generate only certain types of cells

SONAR the use of reflected sound waves to locate objects under water (sound navigation and ranging)

south pole end of a magnet opposite the north pole
Spanish influenza a strain of influenza caused by the H1N1 subtype of influenza virus, which spread across the world in 1918–1920
spirochaete a spiral-shaped bacterium
stable a nucleus that does not change spontaneously. The protons and neutrons in the nucleus are held together strongly.
stamen male reproductive organ of a flower, it consists of the anther and the filament
static electricity a build-up of charge in one place
stigma a female reproductive structure in a flower that receives the pollen
steady state phase *see* plateau phase
stimulants excitatory psychoactive drugs, such as caffeine and amphetamines, that increase or stimulate synaptic transmission
stimulus–response model a system in which a change (stimulus) is detected by receptors leading to a response, which acts to alter and return the variance to normal
storage ring a part of a synchrotron where electrons are trapped in circular orbits by large magnets that steer them around
stomach a large, hollow muscular organ that digests the bolus and secretes acids and enzymes for further digestion and temporary storage
storyboard a visual thinking tool that summarises a sequence of scenes
stomata pores that exchange gases found on the surface of leaves. They are bordered by guard cells that change the size of the opening of the stomata (singular = stoma).
strike-slip fault a break where the rocks on either side of the fault move horizontally due to shearing
style the tube-like female reproductive structure in a flower that connects the stigma to the ovary
subduction a convergent plate boundary where one plate moves under another
suprachiasmatic nucleus (SCN) the biological clock, located in the hypothalamus near where the optic nerves cross
surface protein a protein molecule occurring on the surface of a virus
surface waves seismic waves that travel slower than body waves and only along the surface of the Earth; their energy is lost with depth and distance.
swine flu a strain of influenza caused by the H1N1 subtype of influenza virus, containing a combination of genes from the swine, human and avian flu viruses
switch device that opens and closes the conducting path through which a current flows
switching centres switches mobile phone calls to other base stations or to a fixed telephone system
SWOT analysis chart a visual thinking tool that helps classify or organise thoughts according to strengths, weaknesses, opportunities and threats
symbiotic relationship a very close relationship between two organisms of different species. It may benefit or harm one of the partners.
synaesthesia a condition in which a sensation is produced in one physical sense when a stimulus is applied to another
synapse the gap between adjoining neurons where neurotransmitters travel
synaptic pruning the elimination of the least used and hence weakest synapses (connections between neurons) in the brain during adolescence
synchrotron a building-sized device that uses electrons accelerated to near the speed of light to produce intense electromagnetic radiation. This is used to produce data that can describe objects as small as a single molecule.
syncline a fold in a rock with the narrow point facing downwards
systematic errors errors that are consistently high or low due to the incorrect use or limitations of equipment
T lymphocyte part of the third line of defence, these lymphocytes fight the pathogens at a cellular level. Some T lymphocytes may also attack damaged, infected or cancerous cells.
target map a visual thinking tool that quantifies and ranks based on relevance
tastebuds nerve endings located in your tongue allowing you to experience taste
temporary magnets magnets that stay magnetic while in contact with a permanent magnet, or one that is magnetic for a very short time

tension a stretching force
testosterone male sex hormone
thalamus part of the brain through which all sensory information from the outside (except smell) passes before going to other parts of the brain for further processing
THC the active ingredient in marijuana; also known as delta-9 tetrahydrocannobinol
thermal flash enormous amounts of heat and radiation that spread out from the centre of a nuclear blast
thermoreceptors special cells located in your skin, part of your brain and body core that are sensitive to temperature
thermoregulation the control of body temperature
thermostat a device that establishes and maintains a desired temperature automatically
threshold of hearing the lowest level of sound that can be heard by the human ear
threshold of pain the lowest level of sound that causes pain to the human ear
thyroid gland a small gland in the neck that helps regulate metabolism and growth
timeline a visual thinking tool that shows a sequence of events by date
tinnitus a ringing or similar sensation of sound in the ears, caused by damage to the cells of the inner ear
thermoreceptors special cells located in your skin, part of your brain and body core that are sensitive to temperature
tolerance range the range of an abiotic factor in the environment in which an organism can survive
total internal reflection the complete reflection of a light beam that may occur when the angle between a boundary and a beam of light is small
totipotent the most powerful stem cells that can differentiate into all cell types
trachea narrow tube from the mouth to the lungs through which air moves
transducer a device that converts energy from one form into another form
transform boundary where two tectonic plates slide past one another
transects used to sample an area along a straight line, and is useful when environmental conditions vary along the sample line
transformer device that can increase or decrease voltages for alternating current
translocation transport of materials, such as water and glucose, in plants
translucent allowing light to come through imperfectly, as in frosted glass.
transmissible spongiform encephalopathy (TSE) a degenerative neurological disease caused by prions
transmitted light is passed on from one place to another through space or a non-opaque substance
transmitting antenna a metal structure in which vibrating electrons cause radio waves to travel through the air
transparent a substance that allows most light to pass through it. Objects can be seen clearly through transparent substances.
transpiration stream the movement of water through a plant as a result of loss of water from the leaves
transpiration loss of water vapour mainly through stomata in the leaves (and sometimes from stems)
transverse wave a wave involving the vibration of particles perpendicular to the direction of energy transfer
tremors minor vibrations of the ground that are commonly not felt
trophic level a level within a food chain, food web or food pyramid
tsunami a powerful ocean wave triggered by an undersea earth movement
turgid firm, distended
Type 1 diabetes mellitus a disease in which the pancreas stops producing insulin, so the body's cells cannot turn glucose into energy
Type 2 diabetes mellitus the most common form of diabetes, where the pancreas makes some insulin but does not produce enough
ultrasound sound with frequencies too high for humans to hear
ultraviolet radiation invisible radiation similar to light but with a slightly higher frequency and more energy
umbilical cord stem cells stem cells that can develop into a few types of cells (mainly blood cells and cells involved in fighting disease) and are also being used to treat leukaemia and other blood disorders
universal indicator a mixture of indicators that changes colour as the strength of an acid or base changes, indicating the pH of the substance
unstable an atom in which the neutrons and protons in the nucleus are not held together strongly
ureters tubes from each kidney that carry urine to the bladder

urine yellowish liquid, produced in the kidneys. It is mostly water and contains waste products from the blood such as urea, ammonia and uric acid.

uterus the organ in which a baby grows and develops

vaccination administering a vaccine to stimulate the immune system of an individual to develop immunity to a disease

valid sound or true. A valid conclusion can be supported by other scientific investigations.

variable resistor device for which the resistance can be altered

variable quantity or condition that can be changed, kept the same or measured during an experiment

variolation deliberate infection of a person with smallpox (Variola) in a controlled manner so as to minimise the severity of the infection and also to induce immunity against further infection

vascular bundle group of xylem and phloem vessels within a plant

vectors are organisms that carry and disperse reproductive structures (for example, pollen) of a different species. The term is also used to describe organisms that carry a pathogen between other organisms without being affected by the disease caused by the pathogen.

veins blood vessels that carry blood back to the heart. They have valves and thinner walls than arteries.

vena cava large vein leading into the top right chamber of the heart

Venn diagram a visual thinking tool that analyses and compares by showing common features and different features

venules small veins

vesicle a small fluid-filled, membrane-bound sac in a cell

vibrations repeated, fast back-and-forth movements

villi tiny finger-like projections from the wall of the intestine that maximise the surface area of the structure to increase the efficiency of nutrient absorption. Singular = villus

viroid non-cellular pathogen comprised solely of a short circular RNA without a protein coat

virtual focal point a common point from which rays appear to have come before passing through a concave lens

virus a very simple microorganism that infects cells and may cause disease

visible light a very small part of the electromagnetic spectrum to which our eyes are sensitive

vitamin-deficiency diseases diseases caused by a lack of any vitamins in the diet

vitamins organic nutrients required in small amounts. They include vitamins A, B, C, D and K.

voice coil coil of wire in a loudspeaker that vibrates at the frequency of the electrical signal. This frequency matches the frequency of the sound produced by the cone.

volcanic bomb large rock fragment that falls from an eruption, formed as lava, is blown out of a volcano and is rapidly cooled in the air

volcanoes a landscape feature through which melted rock is erupted onto the Earth's surface

voltage the amount of energy that is pushing electrons around a circuit, per coulomb of charge that flows between two points

voltmeter device used to measure the voltage across a component in a circuit. Voltmeters are placed in parallel with the components.

wave the transmitter of energy without the movement of particles from place to place. The vibration of particles or energy fields is involved.

wave-particle duality model that treats all objects as having both wave-like and particle-like properties. The property observed depends on the observation method chosen.

wavelength distance between two neighbouring crests or troughs of a wave. This is the distance between two particles vibrating in step.

white blood cells living cells that fight bacteria and viruses

wind pollination the transfer of pollen from one flower to another by the wind

x-rays high-energy electromagnetic waves that can be transmitted through solids and provide information about their structure

xerophytes plants adapted to dry conditions possessing structural and physiological adaptations for water conservation

xylem vessel vascular tissue that transports water and minerals from the roots up to the leaves

zero population growth the point at which the population does not increase in size

PERIODIC TABLE

Key

Period 1	1 Hydrogen **H** **1.0**	2 ← Atomic number Helium ← Name **He** ← Symbol **4.0** ← Relative atomic mass

Transition metals (Group 3–Group 12)

	Alkali metals Group 1	**Alkaline earth metals** Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9
Period 1	1 Hydrogen **H** **1.0**								
Period 2	3 Lithium **Li** **6.9**	4 Beryllium **Be** **9.0**							
Period 3	11 Sodium **Na** **23.0**	12 Magnesium **Mg** **24.3**							
Period 4	19 Potassium **K** **39.1**	20 Calcium **Ca** **40.1**	21 Scandium **Sc** **45.0**	22 Titanium **Ti** **47.9**	23 Vanadium **V** **50.9**	24 Chromium **Cr** **52.0**	25 Manganese **Mn** **54.9**	26 Iron **Fe** **55.8**	27 Cobalt **Co** **58.9**
Period 5	37 Rubidium **Rb** **85.5**	38 Strontium **Sr** **87.6**	39 Yttrium **Y** **88.9**	40 Zirconium **Zr** **91.2**	41 Niobium **Nb** **92.9**	42 Molybdenum **Mo** **96.0**	43 Technetium **Tc** **(98)**	44 Ruthenium **Ru** **101.1**	45 Rhodium **Rh** **102.9**
Period 6	55 Caesium **Cs** **132.9**	56 Barium **Ba** **137.3**	57–71 Lanthanoids	72 Hafnium **Hf** **178.5**	73 Tantalum **Ta** **180.9**	74 Tungsten **W** **183.8**	75 Rhenium **Re** **186.2**	76 Osmium **Os** **190.2**	77 Iridium **Ir** **192.2**
Period 7	87 Francium **Fr** **(223)**	88 Radium **Ra** **(226)**	89–103 Actinoids	104 Rutherfordium **Rf** **(261)**	105 Dubnium **Db** **(262)**	106 Seaborgium **Sg** **(266)**	107 Bohrium **Bh** **(264)**	108 Hassium **Hs** **(267)**	109 Meitnerium **Mt** **(268)**

Lanthanoids

57 Lanthanum **La** **138.9**	58 Cerium **Ce** **140.1**	59 Praseodymium **Pr** **140.9**	60 Neodymium **Nd** **144.2**	61 Promethium **Pm** **(145)**	62 Samarium **Sm** **150.4**	63 Europium **Eu** **152.0**

Actinoids

89 Actinium **Ac** **(227)**	90 Thorium **Th** **232.0**	91 Protactinium **Pa** **231.0**	92 Uranium **U** **238.0**	93 Neptunium **Np** **(237)**	94 Plutonium **Pu** **(244)**	95 Americium **Am** **(243)**

- Alkali metal
- Alkaline earth metal
- Transition metal
- Lathanoids
- Actinoids
- Unknown chemical properties
- Post-transition metal
- Metalloid
- Reactive non-metal
- Halide
- Noble gas

Non-metals

Halogens

Noble gases

Group 10	Group 11	Group 12	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
								2 Helium **He** **4.0**
			5 Boron **B** **10.8**	6 Carbon **C** **12.0**	7 Nitrogen **N** **14.0**	8 Oxygen **O** **16.0**	9 Fluorine **F** **19.0**	10 Neon **Ne** **20.2**
			13 Aluminium **Al** **27.0**	14 Silicon **Si** **28.1**	15 Phosphorus **P** **31.0**	16 Sulfur **S** **32.1**	17 Chlorine **Cl** **35.5**	18 Argon **Ar** **39.9**
28 Nickel **Ni** **58.7**	29 Copper **Cu** **63.5**	30 Zinc **Zn** **65.4**	31 Gallium **Ga** **69.7**	32 Germanium **Ge** **72.6**	33 Arsenic **As** **74.9**	34 Selenium **Se** **79.0**	35 Bromine **Br** **79.9**	36 Krypton **Kr** **83.8**
46 Palladium **Pd** **106.4**	47 Silver **Ag** **107.9**	48 Cadmium **Cd** **112.4**	49 Indium **In** **114.8**	50 Tin **Sn** **118.7**	51 Antimony **Sb** **121.8**	52 Tellurium **Te** **127.6**	53 Iodine **I** **126.9**	54 Xenon **Xe** **131.3**
78 Platinum **Pt** **195.1**	79 Gold **Au** **197.0**	80 Mercury **Hg** **200.6**	81 Thallium **Tl** **204.4**	82 Lead **Pb** **207.2**	83 Bismuth **Bi** **209.0**	84 Polonium **Po** **(210)**	85 Astatine **At** **(210)**	86 Radon **Rn** **(222)**
110 Darmstadtium **Ds** **(271)**	111 Roentgenium **Rg** **(272)**	112 Copernicium **Cn** **(285)**	113 Nihonium **Nh** **(280)**	114 Flerovium **Fl** **(289)**	115 Moscovium **Mc** **(289)**	116 Livermorium **Lv** **(292)**	117 Tennessine **Ts** **(294)**	118 Oganesson **Og** **(294)**

64 Gadolinium **Gd** **157.3**	65 Terbium **Tb** **158.9**	66 Dysprosium **Dy** **162.5**	67 Holmium **Ho** **164.9**	68 Erbium **Er** **167.3**	69 Thulium **Tm** **168.9**	70 Ytterbium **Yb** **173.1**	71 Lutetium **Lu** **175.0**
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